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THE ELEMENTS

OF

VITAL STATISTICS

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BY

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THIRD EDITION, ALMOST ENTIRELY REWRITTEN

LONDON
SWAN SONNENSCHEIN & CO., LIM.
NEW YORK: THE MACMILLAN COMPANY
1899

P.G.

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INTRODUCTION.

VITAL Statistics may be defined as the science of numbers applied to the life-history of communities and nations; and in the following pages the chief statistical facts concerning the various phases and stages of life will be in turn presented. The subject naturally divides itself into two sections: first, the sources of information, as the census enumerations, registration of births, marriages, sickness, death, etc.; and second, the information derived from these sources, which will be discussed in detail in the following pages. (See table of contents, pages vii.–xii.)

As the scope of a science widens, it is generally found necessary sooner or later to adopt numerical standards of comparison. In medical science this is found to be especially necessary, though perhaps in no other science is the difficulty of exact numerical statement so great. The value of *experience*, founded on an accumulation of individual facts, varies greatly according to the character of the observer. As Dr. Guy has put it: "The *sometimes* of the cautious is the *often* of the sanguine, the *always* of the empiric, and the *never* of the sceptic; while the numbers 1, 10, 100, and 10,000 have but one meaning for all mankind."

The variable accuracy of individual observers makes us distrustful of generalities founded on imperfect reasoning or defective facts, and necessitates the use of figures. Experience tells us that a certain event is to be expected, while the numerical method can tell us how often it is to be expected. It is sometimes said *that statistics may be made to prove anything;* and no doubt they may be manipulated in such a manner as to make it difficult to detect the fallacies involved in their abuse. But this ignorant or unscrupulous abuse of figures does not discredit their legitimate use, and that they have a very important and perfectly trustworthy application to medical facts will be abundantly shown in the following pages.

PREFACE TO NEW EDITION.

THE steady demand for this work since the first edition was published in 1889, and the numerous inquiries that I have during the last two years received as to when a new edition would be ready, sufficiently indicate that it has fulfilled a useful purpose among those for whom it was specially intended—viz. medical officers of health and medical practitioners studying for a diploma in public health—and that it may in the future be even more widely useful. I take this opportunity of expressing my thanks to many of the above, and to correspondents in the United States and in foreign countries, who have shown their interest in the book, and have made suggestions of improvements which have been utilized in the preparation of the present edition.

The present edition forms an almost entirely new book, although its general plan remains as hitherto. It differs from former editions in regard to both omissions and additions. Much fewer statistical tables are inserted, it being assumed that the reader has access to the last annual report and annual summary of the English Registrar-General, as well as the last decennial supplement, on which an English text-book of vital statistics must necessarily be based. A number of foreign statistical tables have been inserted for comparative purposes, as these are much more difficult of access to most readers. The exact method of construction of a life-table has been given, so that any medical officer of health may be able, by means of the instructions here given, to form a local life-table.

In various parts of the book will be found critical observations on commonly employed statistical methods, and discussions of problems of public health which lend themselves to statistical treatment. These, it is hoped, will increase the interest and value of the book, and lead to local investigations of disease on similar lines.

In a work involving such a mass of statistics it cannot be expected that no errors have crept in. It is believed, however, that these are very few. The author will be grateful for an intimation as to any such errors that may be detected.

ARTHUR NEWSHOLME.

11, Gloucester Place, Brighton,
April 25th, 1899.

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VITAL STATISTICS.

CHAPTER I.

POPULATION.

TO obtain correct and complete vital statistics it is essential to have (1) a correct enumeration of the population classified according to age, sex, occupation, etc.; and (2) a complete and accurate registration of births and deaths and other important events in the life-history of individuals, as marriages and sickness, classified on the same basis as the statistics of population.

An accurate estimate of **population** is the first desideratum, for population forms the natural basis of all vital statistics. In comparing different communities it is necessary to state the deaths and other statistical data in terms of the population, otherwise no true comparison can be instituted.

The actual population is known only by census enumerations. For the years intervening between two census enumerations estimates of the population are made.

The first complete **census** of modern times was taken in the year 1751 in Sweden. In England the first census was in 1801, and then decennially, the tenth being taken on April 6th, 1891. The first census, in 1801, showed the number of males and females of each house and family, and the occupation, classified roughly as agricultural, trading, and others not comprised under these two heads. In 1821 information was first sought as to ages, but it was left optional whether this information should be furnished or not. The first census which could be described as fairly complete was that of 1851, which was organized under Dr. Farr's supervision. It obtained information as to occupation, birthplace, relationship (husband, wife, etc.), civil condition (married, widow, bachelor, etc.), and the number of persons deaf and dumb or blind. At this census, under the powers given by the Census Act, the precise age at last birthday of each person in the country was first demanded.

In the census report of 1881 the age and sex distribution of the population of each urban and rural sanitary authority, as constituted that year, was given for the first time.

At the census of 1891 the schedule contained such new topics of inquiry as the number of rooms and of their occupants in all tenements with less than five rooms, and the important occupational distinction between masters and men, and those working on their own account and without subordinates.

Errors in Census Data. *Ignorance of adults as to their precise age.* Many adults are ignorant of their exact age. Dr. Ogle states that "not improbably the greater number of adults do not know their precise age, and can only state it approximately."* There is a great tendency to return ages as some exact multiple of ten, when really a year or two on one side or other of the precise figure (30, 40, 50, etc.). For this reason decennial age-periods are preferable in calculating death-rates, and 25–35, 35–45, etc., should be chosen in preference to 30–40, 40–50, etc. This tendency does not appear until adult life, and quinquennia can therefore be safely used up to the age of 25 years. The ignorance of many adults as to their exact age and the consequent concentration on multiples of ten is clearly shown in Fig. 1.†

Untrustworthiness of Ages of Young Children. Among children under 5 years of age the vagueness with which parents use the terms "one year old," "two years old," etc., when the children are only in their first or second year respectively, is a cause of considerable error.

Wilful Misstatement of Age occurs more especially among women; thus at every census the young women of 20 to 25 years of age have invariably been more numerous than were the girls aged 10 to 15 at the immediately preceding census. This is clearly brought

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* Dr. OGLE's *General Census Report*, 1891, vol. iv. p. 27. For further particulars on this subject Dr. Ogle's report, which is summarised above, should be consulted.

† Taken from a paper by Mr. R. H. HOOKER, M.A., on "Modes of Census Taking in the British Dominions," *Jour. Royal Statist. Soc.*, June, 1894.

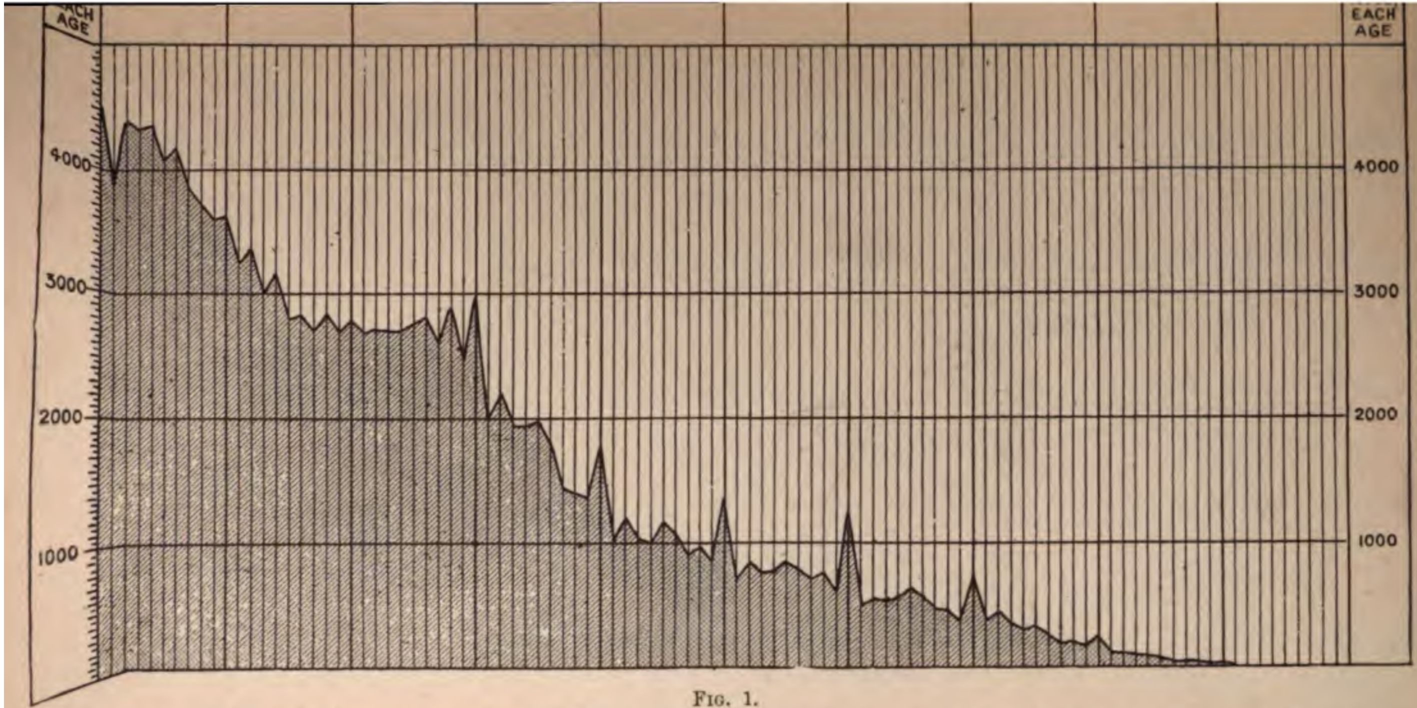

FIG. 1.

Number of Persons in Tasmania living at each Year of Age according to the Census Schedule, showing the tendency to cluster at round Decennial Periods.

out in Fig. 2,* which shows the much greater excess of females over males aged 20 to 30, even after allowance is made for the fact that many men of those ages are abroad.

The Tendency of Old Persons to Overstate their Ages throws some doubt on the figures for ages over 85, and it is preferable to make a single group for all ages over 85.

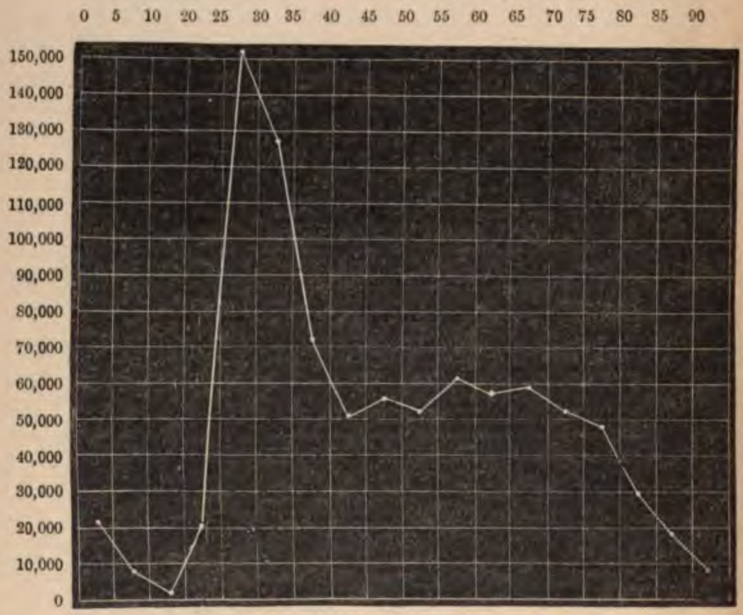

FIG. 2.—Excess of Females over Males at each Age at the Census of England and Wales, 1891.

Physical Infirmities are apt for obvious reasons to be understated. The schedule confines itself to blindness, deafness, and mental derangement, but in respect of all three the difficulty of fixing a standard of degree of impairment necessitating a return, as well as the general unwillingness of persons to admit the existence of any serious infirmity, make the results very inaccurate.

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* From Mr. HOOKER's paper, *Jour. Statist. Soc.*, vol. lvii. part ii. p. 348.

The most serious error, however, occurs in regard to *occupations.* Thus master and servant are commonly confused. In the census schedule of 1891 three new columns were placed, headed respectively "employer," "employed," and "neither employer nor employed," but the results obtained from this attempt at classification are regarded by Dr. Ogle as very untrustworthy.*

Estimates of Population require to be made in the intervals between each census and the next succeeding one. Several methods of varying accuracy have been proposed.

1. The natural increase, that is, the excess of births over deaths since the last census, being known, it would theoretically be possible, if one knew the amount of emigration and immigration, to state the population in any given year. In this country accurate information as to migration has not hitherto been available; and it is difficult to conceive that such information can ever become available under modern conditions of life in respect of the intermigration which occurs between the communities in different parts of the country.

2. The population at the census enumerations in April, 1881 and 1891, being known, it is assumed that the rate of increase is in *arithmetical progression; i.e.*, that the *same annual increase* continues during each year. Thus, given a population in April, 1881, of 32,000, in April, 1891, of 36,000, to find the mean population in 1898.

$$\frac{36000 - 32000}{10} = 400 = \text{annual increase.}$$

$$\frac{400}{4} = 100 = \text{increase from April to Midsummer.}$$

$$\begin{aligned}\text{Therefore mean population in } 1898 &= 36000 + 400 \times 7 + 100 \\ &= 38900.\end{aligned}$$

This method is most fallacious, as it makes no allowance for the increased number of parents year by year, owing to steadily-increasing numbers who year by year attain marriageable age. It assumes, in other words, simple interest when compound interest is really in action.

3. The Registrar-General's method, the one generally adopted, assumes that the *same rate of increase* will hold good as in the

---

* *Census Report*, 1891, vol. iv. p. 36.

previous intercensal period, that is, that the population increases in *geometrical progression.*

The problem is therefore one in compound interest.

Let the net annual rate of increase *per unit of population* be represented by r. Then 1 at the beginning of a year will be $1+r$ at the end of the same year or the beginning of the next year. Similarly, if the same rate of increase continue, the

population at the end of the 2nd year $=(1+r)^2$,
" " " 3rd year $=(1+r)^3$,
" " " nth year $=(1+r)n$.

If we commence with population P, the population at the end of the nth year $=P(1+r)^n$.

The value of r can be ascertained if we know the population at the two last consecutive census enumerations.

Thus if $P'=$ population at the census 1891,
$P=$ " " " 1881,
$P'=P(1+r)^{10}$.

Taking the logarithm of each side of the equation,

$$\log. P' = \log. P + 10 \log. (1+r),$$
$$\therefore \log. (1+r) = \tfrac{1}{10} (\log. P' - \log. P).$$

Whence $1+r$ is easily obtained from a table of logs.

For example, if the census population of a town is 32,000 in 1881, and 36,000 in 1891, what is the mean population in 1895?

(*a*) *First find the rate of increase in* 1881–91.

$$\text{Here } P = 32000,\ P' = 36000,$$
$$\log. P' = \log. 36000 = 4{\cdot}556303,$$
$$\log. P = \log. 32000 = 4{\cdot}505150,$$
$$\log. P' - \log. P = {\cdot}051153,$$
$$\tfrac{1}{10} (\log P' - \log P) = {\cdot}0051153 = \log. 1+r.$$

(*b*) *Apply this to the increase in the next* 4¼ *years.*

$$\text{Here } \underset{(1895)}{P} = \underset{(1891)}{P} (1+r)^{\frac{17}{4}},$$
$$\log. \underset{(1895)}{P} = \log. 36000 + \tfrac{17}{4} \log. (1+r),$$
$$= 4{\cdot}556303 + \tfrac{17}{4} ({\cdot}0051153),$$
$$= 4{\cdot}556303 + {\cdot}0217400,$$
$$= 4{\cdot}578043.$$

And from the table of logs. the population corresponding to this number $=$ 37848 $=$ population at the middle of 1895.

It must be remembered that the *mean population* of the year is taken as the basis of calculation of mortality and other rates, which involves an estimate, even in the census year, for the three months between the census and midsummer. It would therefore be advantageous to have the census enumerations at the end of June as well as to have them more frequently.

4. The results obtained by the last method may be to some extent checked for any given district by ascertaining *the number of inhabited houses* for the year from the assessment books, and then multiplying this by the average number of inhabitants in each house, as ascertained at the last census. This method, although it forms a useful check on the preceding method, involves the fallacy that new houses may be of a different class from those previously in existence, and may therefore have a different number of occupants.

5. If we *assume that the birth-rate per* 1000 *inhabitants remains fairly constant*, an additional means of checking the population is obtained. The number of registered births in a district in a given year being known, it is only necessary to calculate the population on the basis of the birth-rate known to have held good during the last census year. This method is becoming less reliable, owing to the decline in the birth-rate. In 1895 the birth-rate in England and Wales was 30·4, as compared with 31·4 in 1891. The number of births registered in England and Wales in 1895 having been 922,291, the population in that year, on the basis of the birth-rate in 1891, would be

$$\frac{922291 \times 1000}{31\cdot4} = 29373248,$$

whereas the estimated population based on the Registrar-General's method of calculation (page 6) was 30,383,047. The birth-rate, however, still gives a valuable clue to errors in the estimated populations of large towns. If the deviation from the birth-rate of the preceding ten or fifteen years is greater in any given year than in the immediately preceding years, there is strong reason for suspecting that the estimate of population is incorrect, unless great changes in the industrial condition of a community can be adduced in explanation of the anomaly.

Similar objections may be urged against estimates based on returns of school-attendance, as the proportion of children at school-ages will follow the births of preceding years.

Criticism of the Official "Estimates." The assumption that the same rate of increase holds good in two successive decennial periods appears to be, under present conditions in this country, the least unsatisfactory basis for estimation of the population in an intercensal year. But it frequently gives unsatisfactory results, whether applied to the whole country, or to particular communities in it. Thus the decennial rate of increase of the English population in the ten periods elapsing since the first census in 1801 has been 14·0, 18·1, 15·8, 14·5, 12·9, 11·9, 13·2, 14·4, and 11·6 per cent. respectively. Had the rate of increase in 1881–91 remained as in 1871–81 the population of England and Wales would have increased from 25,974,439, in 1881, to 29,704,468, instead of to 29,002,525, the population enumerated in 1891. The figures for great towns bring out much more strikingly the errors that may arise from the assumption that the same rate of increase continues as in the previous decennium. Thus at the census of 1891 the population of Salford was found to be 20·9 per cent. below the estimate based on the rate of increase in 1871–81; that of Liverpool 16·6 per cent., and of Nottingham 15·6 per cent. below the corresponding estimate; while at the opposite extreme the population of Newcastle-upon-Tyne was 13·6 per cent. above, and of Portsmouth 10·9 per cent. above the estimate. The above are extreme instances; but the method is open to objection, even when the error is of smaller magnitude. The proper remedy is more frequent enumerations of population.

A Quinquennial Census would go far to remedy the present uncertainties. Such a census is practised in France and Germany (triennial in some German states), in New Zealand, Queensland, Manitoba, and the North-Western territory of Canada, as well as in many of the states and several territories of the American republic. It is true that there are not as powerful reasons for a quinquennial census as on the Continent, where it is required for military purposes; nor is there the same necessity as in many American states, where the increment of population is by leaps and bounds, and not steadily, as in most parts of our own country. Still, however, there are very strong reasons why a quinquennial census should be adopted, the chief one being that comparative vital statistics depend for their accuracy on estimates or enumerations of population, and that estimates necessarily become less trustworthy the more remote they are from enumerations.

Vital statistics furnish the basis on which sanitary reforms rest, especially in regard to legislation. Dr. Farr may in this sense be called the father of sanitary science. There are also political reasons for a quinquennial census, as political representation for both imperial and local purposes is likely to be based in future on a more strictly numerical basis. In addition, a more frequent census would lead to the work being better done, owing to less difficulty in collecting a sufficient staff of intelligent enumerators and greater experience on their part. The chief objection is the expense of the enumeration. In 1881 the census for Great Britain and Ireland cost approximately £185,000, or about five guineas per 1000 of enumerated population. There is little doubt that this expense of each enumeration might be reduced by more frequent enumerations, but if not, the value of the results obtained would abundantly justify the double expenditure on the present basis. In the report presented to both Houses of Parliament in 1890 by the Committee appointed by the Treasury to inquire into certain questions connected with the taking of the census, it was recommended "that the number of the population and its distribution as regards age and sex be ascertained midway between the decennial periods at which a full census is taken," but unfortunately this recommendation has not been acted upon in 1896, except for London, on the initiative of the London County Council. This intermediate London census is rendered much less valuable by the absence of information as to the age and sex of the population.

Effects of Migration on Population. The relative effect of the two factors governing the increase of population in England—natural increase and migration—may be seen from the following figures from the *Census Report*, 1891, vol. iv. pp. 5–6 :—

Intercensal Period.	Increase per cent. by Births.	Decrease per cent. by Deaths.	Gain per cent. by excess of Births over Deaths, or Natural Increase.	Gain per cent. as determined by Actual Enumeration	Difference, being loss or gain by excess of Emigration over Immigration, or of Immigration over Emigration.
1841–51	34·64	23·73	10·91	12·89	+1·98
1851–61	36·19	23·58	12·61	11·93	−0·68
1861–71	37·56	23·98	13·58	13·19	−0·39
1871–81	37·89	22·80	15·09	14·36	−0·73
1881–91	34·24	20·27	13·97	11·66	−2·31

With the exception of the first period the natural increase was greater than the actual increase of population, and emigration was in excess of immigration. The decline of natural increase in 1881–91, as compared with 1871–81, is due to a lowered birth-rate and not to increased mortality, the mean annual death-rate in 1881–91 having been lower than in any earlier decennium on record.

It is unfortunate that there are no accurate means of determining in what degree the increased loss by excess of emigrants over immigrants in 1881–91 was due to increased emigration, or in what degree, if any, to diminished immigration.* In Ireland there is a special machinery for collecting emigration returns, and from these returns, combined with the balance of births over deaths, an estimate very near the truth can be obtained.

Internal Migration. In urban districts with fixed boundaries the assumption that the rate of increase of the preceding decennium will continue becomes less accurate in proportion to the extent in which the area of the districts in question becomes covered by houses. Thus the population of the County of London increased at the rate of 17·2 per cent. in 1871–81, at the rate of 10·3 per cent. in 1881–91. It is highly improbable that the increase of the next decennium will approach 10 per cent., the population having extended in a centrifugal manner, and overstepped the geographical boundaries of the County of London. The present anomalies of parochial parishes, federated into registration districts, which often do not coincide with county boundaries, require adjustment. It may happen, as in the preceding instance and in many similar instances for other large towns, that in refusing to extend the statistical area of a town whose population is rapidly overstepping the municipal boundaries, an area which once included the whole of a town finally includes only its centre, the statistics of the suburbs of the town being arbitrarily separated from those of the centre to which they normally belong.

Migration between Urban and Rural Districts. It is difficult to frame a definition which shall satisfactorily distinguish between urban and rural districts. Many small towns, which form the centres of agricultural districts, and which have no important industries apart from that of the rural population surrounding them, are really rural, and not urban in their characteristics. Dr.

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* See a paper by Mr. E. CANNAN, M.A., *Jour. Royal Statist. Soc.*, vol. lxi. part i.

Ogle (*Census Report*, 1891, p. 10) proposes two lines of arbitrary division. In the first a population of 10,000, and in the second of 5000, constitutes the point at which a town ceases to come under the rural category. According to the first of these standards the urban population had grown by 16·54 per cent. between 1881 and 1891, while the remaining population had increased by only 4·57 per cent. According to the second of these standards the urban population had increased by 16·05 per cent., the remaining population by 3·29 per cent. If the Local Government divisions into urban and rural sanitary districts be taken, the corresponding increase of urban population was 15·4 per cent., of rural population 2·98 per cent.

Thus, whichever standard is adopted, there has been no literal depopulation of rural districts, but only a smaller rate of increase than in urban districts. Somewhat varying results are obtained when we classify the counties according to the percentage decrease in rural population between 1881 and 1891. The greatest decrease is shown in Montgomeryshire (11·68 per cent.), Cardiganshire (9·20 per cent.), Radnorshire (7·58 per cent.), and Flintshire (7·01 per cent.). Twelve English and eight Welsh counties, out of the total 54 (including the three divisions of Yorkshire), show decreases. The only English counties of any numerical importance which show more than a trifling decline of rural population are Lincolnshire (4·29 per cent.), North and East Ridings of Yorkshire (4·62 and 2·41 per cent.), Cornwall (3·76 per cent.), Bedfordshire (2·55 per cent.), and Wiltshire (2·14 per cent.).

As illustrative of the migration townwards may be adduced the fact that while in 1801 for every 100 persons in England and Wales there were 10·78 persons in London, this number had increased in 1891 to 14·52.

The fact that the population of towns in every country is largely replenished from rural districts is shown by the following figures.* Out of a thousand inhabitants in each of the following cities the number of native-born persons was as follows:—

Antwerp	661	Christiania	425
London	629	Budapest	424
Hamburg	543	Berlin	424
Copenhagen	524	Stockholm	416
Glasgow	513	Paris	349
Milan	484	Vienna	345
Rome	446		

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* "The Laws of Migration," by Mr. E. G. Ravenstein, *Jour. Statist. Soc.*, June, 1889.

The general result is that towns and manufacturing districts everywhere grow more rapidly than rural districts. "This is a necessary consequence of the rigidly limited amount of land available for agriculture, and the practically unlimited amount of material available for manufacturing processes." *

Dr. Longstaff has investigated the same subject from an international standpoint,† and shows that "for the last forty years in every country throughout the world, new and old alike, the towns, and especially the large towns, have increased in population more rapidly than the rest of the country. . . . The causes, whatever they may be, affect alike Celt and Anglo-Saxon, Teuton, Latin, and Magyar." There can be little doubt that one chief cause of this tendency for the population to aggregate in towns is the greater pleasure and excitement enjoyed by townspeople. Dr. Longstaff points out that improved communications are the chief exciting cause which render this greater urban aggregation practicable. With the improved means of locomotion must be associated the enormously increased use of machinery in every department of industry. The fact that corn can now be brought from Canada or Russia cheaper than it can be produced in England, tends to the same result. Gradually each country is becoming readjusted to produce the greatest amount of material at the expenditure of the smallest amount of labour, whether it be corn or manufactured goods, and the improved means of communication, national and international, enable this to be done, almost irrespective of distance, and determine the preponderance of urban or rural population.

Birth-Places of the Population. The statistics as to birth-places of the population throw much incidental light on the question of migration. Thus at the two last enumerations, out of every 10,000 persons in England and Wales enumerated there were—

Birth-place.	In 1881.		In 1891.
England and Wales	9,570	...	9,614
Scotland	98	...	97
Ireland	216	...	158
Islands in British Seas	11	...	11
British Colonies or Dependencies	36	...	38
Foreign parts (British subjects and foreigners)	67	...	80
At sea	2	...	2
	10,000		10,000

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* Dr. Ogle on "The Alleged Depopulation of the Rural Districts of England," *Jour. Statist. Soc.*, June, 1889.

† "Rural Depopulation," *Jour. Statist. Soc*, Sept., 1893.

Of the 29,002,525 persons enumerated in this country at the last census 961 per 1000 were natives of England and Wales. In only nine counties was the actual growth, as shown on enumeration, in excess of the natural growth by excess of births over deaths.* Of the natives of England and Wales who were in the country at the date of the census 74·86 per cent. were enumerated in their native counties, as compared with 74·04 per cent. in 1871. Thus although emigration to foreign countries increased enormously between 1881 and 1891, there was, notwithstanding increased facilities of communication and greater knowledge as to the conditions of life in parts outside their immediate localities, no corresponding increase of inter-migration within the borders of England and Wales.

The proportion of Irish in the English population had declined by 18·5 per cent. between 1881 and 1891. This has been associated with a gradual decline in the population of Ireland itself. The proportion of Irish in England and Wales to Irish in their own country increased with each census up to 1881 and then declined. Thus in 1841 there were 36 Irish in this country to 1000 in Ireland itself; in 1851 there were 80; in 1861 there were 105; in 1871 there were 107; in 1881 there were 111; in 1891 there were 100 to every 1000 in Ireland.

The Scotch element in the English population has increased steadily from 6·5 per 1000 in 1841 to 98 per 1000 of the total population of England in 1881.

Trans-Oceanic Emigration. Mr. Geoffrey Drage† quotes the trans-oceanic emigration statistics drawn up by Signor Bodio for all European countries during the period 1880–92, and comparing these with the enumerated populations of the same countries for the years 1889–91, obtains the following estimate of the proportion per 1000 lost by the various countries:—

Country.	Average Emigration.	Proportion per 1000 of Population.
Norway	18,836	9·19
United Kingdom	247,279	6·54
Sweden	30,709	6·39
Portugal	18,901	3·97
Denmark	8,344	3·84
Italy	102,466	3·37
Switzerland	8,007	2·74

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* *Census Report*, 1891, vol. iv. p. 61.

† "Alien Immigration," *Jour. Statist. Soc.*, March, 1895.

Country.	Average Emigration.		Proportion per 1000 of Population.
Germany	123,985	...	2·50
Spain	38,248	...	2·18
Hungary	17,717	...	1·22
Holland	5,107	...	1·13
Austria	23,050	...	0·96
Belgium	4,371	...	0·72
Russia in Europe	58,192	...	0·63
France	10,429	...	0·25

From the point of view of the countries losing the above emigrants the proportion to the total population must be considered, and from this standpoint Russia's loss is a negligeable amount. From the point of view of the countries receiving the migration it is evident that the British, German, Italian, and Russian emigrations are of the very first importance. The most remarkable fact in the preceding table is that, "with the exception of the United Kingdom, the countries sending out the largest numbers of emigrants are by no means always those in which the population is densest. Germany and Italy certainly stand high in the scale of density of population, but not so high as Holland and Belgium, yet the Dutch and Belgian emigration is both absolutely and relatively small. Norway and Sweden, on the other hand, combine an exceptionally heavy emigration with a scanty population, and in view of their rapid rate of natural increase may be said to be thinly peopled in consequence of this drain upon their resources. French emigration is so small as to exercise scarcely any appreciable effect, and Austrian emigration, though absolutely large, scarcely amounts to 1 per 1000 of the population."

CHAPTER II.

POPULATION FROM AN INTERNATIONAL STANDPOINT

THE habitable globe is limited in area. The relative rate of natural growth of the population of each country by excess of births over deaths has therefore a most important bearing on the final race characteristics of the population of the world.

Fig. 3 shows the average birth-rate and death-rate of the different European countries for the five years 1891–95, while the distance between the two columns represents the natural increase in each country. The countries are arranged in the order of the magnitude of their annual natural increase, beginning with Prussia, in which it was 14·1, and ending with France, in which it averaged only ·08 per 1000 of the population in the five years 1891–95.*

From the preceding figures it is easy to calculate in how many years the population of each country would take to double itself by natural increase.

$$\text{Here } P' = PR^n,$$
$$i.e., \ 2\,P = PR^n,$$
$$\therefore R^n = 2.$$
$$n \log. R = \log. 2,$$
$$n = \frac{\log. 2}{\log. R} = \frac{\log. 2}{\log. (1+r)}.$$

In England $r = \cdot 0118$,

$$\therefore n = \frac{\log. 2}{\log. 1\cdot 0118} = \frac{\cdot 301030}{\cdot 005093} = 59\cdot 1 \text{ years.}$$

In Prussia the population would double itself by natural increase in 49·2 years; in England in 59·1 years; in Italy in 65·7 years; in Austria in 74·1 years; and in France in 591 years.

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* In Fig. 3 the birth-rate of France should be 22·4, not 22·6 as given in the figure.

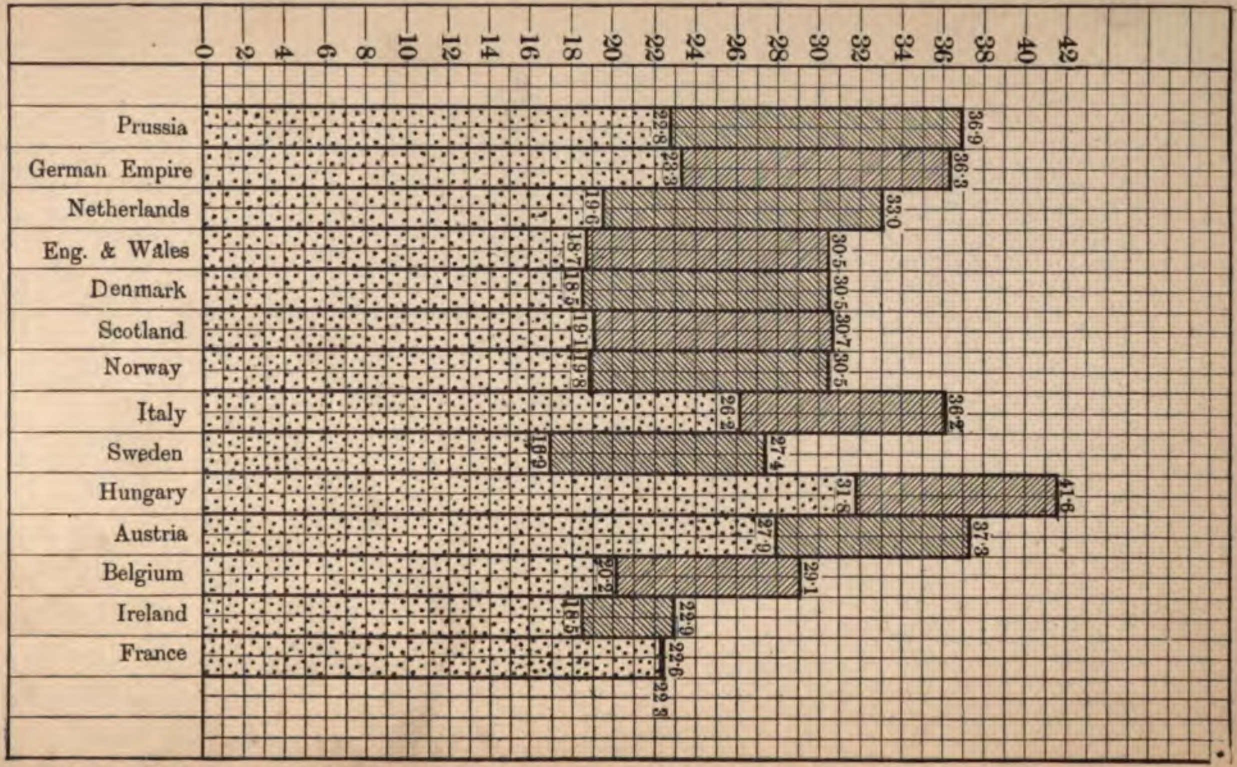

FIG. 3.—Showing mean birth-rate, death-rate, and rate of natural increase in the chief European countries, 1891–95.

Dotted portion = Death-rate. Diagonally-marked portion = Rate of Natural Increase.

These results of natural increase of population are disturbed by the effects of migration. It is therefore of interest to ascertain the net results as determined by all the factors at work, so far as they can be ascertained from historical records.[*]

In 1789 the populations of the great European Powers were as follows:—

	Millions.
France	26
Great Britain and Ireland	12
Russia	25
German Empire	28
Of which Austria	18
Prussia	5

In 1815 the relative populations were as follows:—

	Millions.
France	29·5
Great Britain and Ireland	19
Austria	30
Prussia	10
Russia	45
German Confederation (in which were included parts of Austria and Prussia)	30

In 1890 the relative populations are stated by M. Bertillon to be as follows:—

	Millions.
France	38 3
Great Britain and Ireland	38·1
Austro-Hungary	43·2
German Empire	49·4
Russia in Europe	100 2
Italy	30·5

The most remarkable contrast shown in the preceding tables is between Great Britain and Ireland with a population of 12 millions in 1789 and of 38 millions in 1890, and France with a population of 26 millions in 1789 and of only 38 millions in 1890, not reckoning external colonies in either instance.

Any conclusion from the above purely European figures would be erroneous which did not take into account the rapid growth of population in North and South America, in Australia, and in Africa. In North America and in Australia, and to a less extent in South Africa, this rapidly increasing population is chiefly English-speaking.

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[*] LEVASSEUR, *Annales de Démographie*, 1879, and J. BERTILLON, *Eléments de Démographie*, 1896, p. 8.

The increasing proportion borne by the population of the English self-governing colonies to that of the mother-country is shown in the following table arranged by Dr. Longstaff.* The population of the United Kingdom at each census being taken as 100, it will be seen that the united population of British North America and Australasia increased in 50 years from 7 to 21.

PROPORTION BORNE BY POPULATION OF NORTH AMERICAN AND AUSTRALASIAN COLONIES TO THAT OF THE MOTHER-COUNTRY.

Census.	United Kingdom.	Colonies.
1841	100	7
1851	100	11
1861	100	16
1871	100	18
1881	100	21

The United States of America show the most gigantic increase of population of which we have records. In 110 years the population has become multiplied 21 times over. It would not be correct to say that the population has multiplied itself to this extent, as the greater part of the increase is due to immigration.

Further particulars on the subject of this chapter are contained in LONGSTAFF'S *Studies in Statistics*, 1891, pages 22–168. The population and chief vital statistics of the chief European countries are given on pages cviii.–cxxi. of the *Fifty-Eighth Annual Report of the Registrar-General in England*, or the corresponding parts of the annual reports for other years.

The annual summary (page xxviii. of the report for 1896) and the corresponding quarterly reports and weekly returns of the Registrar-General give the population and chief vital statistics of 36 cities, of which 33 are foreign, European, American, Egyptian, and Indian cities.

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* *Studies in Statistics*, 1891, p. 151.

CHAPTER III.

REGISTRATION OF BIRTHS AND DEATHS.

NEXT to a correct enumeration of population the accurate and complete registration of births, marriages, and deaths constitutes an essential basis of vital statistics. The question of registration of disease will be discussed in the next chapter.

Twenty-three years ago Edmund Parkes stated the importance of statistics of births and deaths in the following words: "The attention now paid to public health is in a large degree owing to the careful collection of the statistics of births and deaths, and of the causes of death, made in England during the last forty years. It may truly be said, indeed, that not only all Europe, but gradually the entire world, has been influenced by the work of the Registrar-General of England. We are now able to determine with some precision the limits of mortality and its causes, and are being led up to the consideration of the causes which bring about a high death-rate."

History of Registration. The office of Registrar-General of England was created in 1836, and civil registration began as the result of an Act of Parliament on July 1st, 1837. The first of the series of annual reports of the Registrar-General was published in 1839, and to this first report Dr. W. Farr, who acted as "Compiler of Abstracts" in the newly created General Register Office, contributed the first of that long series of letters, addressed to the Registrar-General, on the causes of death in England, with which is wrapped up our knowledge of the vital statistics of this country.

Successive amendments to the law of registration were made, and in 1870 a new law was enacted rendering the registration of births and deaths compulsory.

In the 39½ years before registration became compulsory the registration of births was defective, the proportion of unregistered births being estimated at about 5 per cent. Only a small proportion of deaths were believed to have escaped registration, though in a considerable proportion the medical certificate of cause of death was either unsatisfactory or altogether wanting. The returns of

1876 show the excellent effect of the compulsory law. The stated birth-rate of that year, 36·6 per thousand, was the highest on record, being 1·2 per thousand higher than the average for the ten previous years; while the number of uncertified deaths had greatly decreased.

The Law as to the Registration of Births. The Act of 1836 provides that the father or mother of a child, or in default of these the "occupier" of the house in which the child was born, or each person "present at the birth," or the persons "in charge of the child," must give notice to the registrar within 42 days of its birth, and sign the register in his presence.

The medical practitioner in attendance at the birth may evidently, in exceptional instances, come within the scope of the above requirement. Similarly, if no notice has been given by any-one within the forty-two days, the registrar may, by notice in writing, require the medical man, or other persons present at the birth, to attend personally at his office and give him the necessary information. The official instructions to registrars, however, enjoin upon them not to call upon persons present at the birth until they have failed to obtain the information from both the parents and the occupiers; so that, in practice, medical men are seldom troubled in this matter.

Registration of Births in relation to Vaccination. The Vaccination Act of 1867 makes it obligatory on the registrar at or within seven days of the time when a birth is registered to give notice to the parent or other responsible person requiring the infant to be vaccinated within three months* of its birth, and stating particulars as to the hours of attendance at and place for public vaccination.

By the Vaccination Act of 1871 every registrar must at least once a month transmit to each vaccination officer, whose district is wholly or partly comprised within his registration district, a true return of the births and deaths of infants under one year of age which have been registered since the last return was made. A fee of 2*d.* is payable for each entry.

The Law as to Registration of Deaths.†

"The law relating to the registration of deaths in England and Wales is mainly to be found in the Registration Act, 1836, as amended by the Births and Deaths Registration Act, 1874. Under Sections 10 and 11 of the last-mentioned Act personal information of every death has to be given to the registrar of the district within five days of its occurrence by the nearest relatives of the deceased present at the death or in attendance during the last illness. In default of information of the death being given to the registrar by these persons, such information is to be given to him by the other persons mentioned in the section. Relatives present at the death or in attendance during the last illness who fail to comply with these provisions are liable to a penalty of 40*s.*

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* The Vaccination Act, 1898, alters this period to six months.

† The following particulars are taken chiefly from the Report of the Select Committee of the House of Commons on Death Certification, September, 1893.

"If the person required to give information of the death to the registrar send to him a written notice of its occurrence, accompanied by a medical certificate of its cause, the personal information required to be given to the registrar need not be given within five days, but must be given within fourteen days (sec. 12, Act of 1874).

"The law, however, does not require either notification or registration as a condition precedent to burial or to disposal of the body. It is provided, that any person who buries or performs any funeral or religious service for the burial of any dead body as to which no coroner's order for burial or registrar's certificate of registration or of notification has been produced to him, shall, subject to a penalty of £10 in the event of default, give notice thereof in writing to the registrar within seven days. A like penalty is imposed by Section 11 of the Burials Act, 1880 (as explained by Section 2 of the Burials Act, 1881), upon the person having charge of or being responsible for a burial under that Act (sec. 17, ditto).

"The registrar may register a death—

> (A.) On the statement of a 'qualified informant' attending personally for the purpose, and producing a medical certificate of the cause of death, when the deceased has been attended in the last illness by a registered medical practitioner. When there has been no such medical attendance the registrar must accept the 'qualified informant's' statement as to the cause of death.
>
> (B.) On the certificate of the finding of a coroner's jury, where an inquest has been held.

"The registrar is empowered to issue a certificate to the effect that he has registered or received notice of a death, as the case may be, on production of which certificate burial can take place.

"The certificate is to be issued gratuitously to the person giving the information or sending the notice, or in the case of a burial under the Act of 1880 to the person having charge of or being responsible for the burial (sec. 17, ditto).

"The person receiving the certificate is bound, under a penalty of 40*s.*, to deliver it to the person who buries or performs any funeral or religious service for the burial of the deceased (sec. 17, ditto).

"(A.) *Registration of the Cause of Death on the Statement of a Qualified Informant.*—Where a person has been attended during his last illness by a registered medical practitioner, it is the duty of the practitioner to give a certificate stating the cause of death to the best of his knowledge and belief. If he fails to give a certificate he is liable to a penalty of 40*s.*, and if he gives a false certificate he is liable, on summary conviction, to a fine of £10, or on indictment to seven years' imprisonment. He may, however, refuse to give a certificate on reasonable grounds (sec 20, ditto).

"The certificate is to be given by the medical man to the person required under the Registration Act to give information concerning the death, called the 'qualified informant,' whose duty it is to deliver it to the registrar under a penalty of 40*s.* (sec. 20, ditto).

"(B.) *Registration on the Certificate of the finding of a Coroner's Jury.*—A death may be registered upon the certificate of the coroner, who is bound, after the termination of an inquest on any death, to send to the registrar such certificate of the finding of the jury within five days, the jury being bound to inquire of and to find the particulars for the time being required by the Registration Acts to be registered concerning the death. Where an inquest has been held a medical certificate of the cause of death need not be given to the registrar, but the certificate of the finding of the jury furnished by the coroner is sufficient, and the registrar is bound to take the finding of the jury in the words of the coroner, and this finding supersedes any previous certification of the cause of death. The coroner may order burial before registry of the death, but only after inquest, and unless an inquest is held there is no power to register a death upon the coroner's certificate (sec. 45, ditto).

"If a registrar becomes aware of a death that has not been registered in accordance with the ordinary regulations in that behalf, he may, at any time after the expiration of fourteen days, and within twelve months from the day of such death, call upon the person upon whom the registration of the death would have devolved to attend before him at a specified time, for the purpose of giving information as to such death (sec. 13, ditto).

"After the lapse of twelve months a death can only be registered upon the authority of the Registrar-General (sec. 15, ditto)."

No fee is payable by the informant when a birth or death is registered, unless the registrar is required, in pursuance of a written requisition, to attend the private house in which the birth or death has occurred, in which case the informant must pay a fee of one shilling.

Relation of Registrar to Medical Officer of Health. By sec. 28 of the Births and Deaths Registration Act, 1874, each urban or rural Sanitary Authority can require the Registrar of Births and Deaths to supply returns of the births and deaths within his district. These returns are usually made weekly, but an immediate return can be required of deaths from infectious diseases. A fee of 2*d*. for each return and for each entry of deaths is payable by the Sanitary Authority. The medical officer of health can require a complete copy of the entry in the register, including the occupation of the deceased, as well as the particulars in the official form of certificate given on page 31.

Still-Births. No record of still-born children may be made in a register of births or deaths. Even when an inquest has been held, and when, according to the finding of the jury, there was not sufficient evidence that the child was born alive (*i.e.*, that it lived after complete separation from the body of its mother) no record may be made. But if a child be born alive, no matter how soon it may die, both the birth and the death must be registered.

Under section 18 of the Births and Deaths Registration Act of 1874 a penalty of £10 is imposed upon any person who buries the body of a deceased child as if it were still-born, and a like penalty is imposed upon any person who has control over a burial-ground, and who permits the body of a deceased child to be buried in such burial-ground as if it were still-born, or who buries or permits to be buried in such burial-ground any still-born child without a written certificate from a medical practitioner that such child was not born alive, or a declaration from a qualified informant or a coroner's order, if there has been an inquest.

The Report of the Committee of the House of Commons on Death Certification (p. 22) says: "There is reason to think that if the statistics on the subject could be obtained, it would be found that the number of children buried in the United Kingdom annually as still-born is enormous"; and the Committee are further convinced that "the absence of legal requirement that such births should be registered prior to disposal of the bodies is fraught with very serious danger to child-life." This is especially so in the case of illegitimate children.

There being no trustworthy English figures on the subject, the following from the official returns of Hamburg are of interest. During the years 1882–96 inclusive the proportion of still-born to total births varied from 2·91 to 3·67 per cent. The proportion among boys varied from 2·89 to 4·24 per cent.; among girls from 2·91 to 3·58 per cent. The proportion among infants born in matrimony varied from 2·79 to 3·40; among illegitimate infants from 4·47 to 6·40 per cent. In the same returns still-births are classified according to whether they were premature, and whether the death occurred during or before parturition.

Uncertified Deaths. The absence of a medical certificate of cause of death does not necessarily involve a report to the coroner by the registrar. He must report the death to the coroner "where it appears that the death was caused directly or indirectly by violence, or was attended by suspicious circumstances, and whenever the death is stated to have been sudden, or the cause of death is stated to be 'unknown.'" This applies to all cases, whether certified by a registered practitioner or not. In other cases the registrar may accept the statement of the informant as to the cause of the death, and the information thus accepted may include a certificate from an unregistered practitioner.

The registrar must report to the coroner the death of every infant which dies in a house registered under the Infant Life Protection Act, 1872. It is the duty of the local authority to furnish soon after the 1st January in each year a complete list of all such registered houses, and to notify from time to time any alteration therein. If the local authority omits to furnish these lists it is the registrar's duty to apply for them.

In 1895 the causes of 91·68 per cent. of the total deaths in England and Wales were certified by registered medical practitioners, and the causes of 6·00 per cent. by coroners after inquest, while the causes of the remaining 2·32 per cent. of the total deaths were not certified. The 13,173 uncertified cases included the deaths of infants who had been attended only by midwives, and those of persons who had been attended by unregistered practitioners, as well as those of persons who had received no "medical" attendance of any kind. In registration counties the proportions per cent. of unregistered deaths ranged from 0·71 in London and 0·88 in Wiltshire to 4·58 in Huntingdonshire, 4·78 in North Wales, and 5·88 in Herefordshire.* In the same year just one-third of the uncertified deaths were of infants under three months of age, and these deaths were 6·27 per cent., or about one in sixteen of all the deaths under three months of age. The proportion of uncertified deaths fell abruptly to 2·49 per cent. between three and twelve months of age; the minimum, 0·85 per cent., being reached at fifteen to thirty-five years of age, after which it gradually rose with advancing age.

* *Fifty-Eighth Annual Report of the Registrar-General.*

Inquests. When an inquest is held on any dead body it is the duty of the coroner to send a certificate to the registrar within five days after the finding of the jury is given, giving full particulars as to this finding. The only person upon whom the duty devolves of deciding whether cases are suspicious in any case, and if so, of referring them to the coroner, is the registrar. It seems very desirable that this option should be removed from him and transferred to the coroner. In a considerable proportion of uncertified deaths that are submitted by the registrars to the coroner the latter decides in an informal manner that no inquest was required after an investigation made by his officer, who frequently is a parish beadle or police officer. Such a procedure would be justifiable if a private medical investigation were instituted, but as matters now stand there is little reason to doubt that crimes occasionally remain undetected, which skilled investigation would have brought to light. Even when a coroner's inquest is held the result may be little more satisfactory, the inquiry being often perfunctory and its result dubious, owing, among other causes, to the fact that autopsies have not infrequently been omitted.

The death on account of which an inquest is held is very commonly registered subsequently as "from natural causes," the coroner considering his sole function to be the detection of crime, and ignoring entirely the medical problems toward the solution of which he might contribute. In other inquest cases the certification is almost equally defective, the cause of death being returned as "sudden death," "death by the visitation of God," "found dead," etc. Such returns are useless for classification. No coroner's inquest is satisfactory which does not include a post-mortem examination by a competent medical practitioner.

Recommendations of Committee of House of Commons on Death-Certification (1893). The Committee give the following summary of their recommendations:—

"(1.) That in no case should a death be registered without production of a certificate of the cause of death signed by a registered medical practitioner or by a coroner after inquest, or in Scotland by a Procurator Fiscal.

"(2.) That in each sanitary district a registered medical practitioner should be appointed as public medical certifier of the cause of death in cases in which a certificate from a medical practitioner in attendance is not forthcoming.

"(3.) That a medical practitioner in attendance should be required, before giving a certificate of death, to personally inspect the body, but if, on the ground of distance or for other sufficient reason, he is unable to make this inspection himself he should obtain and attach to the certificate of the cause of death a certificate signed by two persons, neighbours of the deceased, verifying the fact of death.

"(4.) That medical practitioners should be required to send certificates of death to the registrar, instead of handing them to the representatives of the deceased.

"(5.) That a form of certificate of death should be prescribed, and that in giving a certificate medical practitioners should be required to use such form.

"(6.) That it should be made a penal offence to bury or otherwise dispose of a body, except in time of epidemic, without an order from the registrar stating the place and mode of disposal, which order, after it has been acted upon, should be returned to the registrar who issued it.

"(7.) That it should be made an offence to retain a dead body unburied or otherwise legally disposed of beyond a period not exceeding eight days, except by permission of a magistrate.

"(8.) That the practice of burial in pits or common graves should be discontinued.

"(9.) That still-births which have reached the stage of development of seven months should be registered upon the certificate of a registered medical practitioner, and that it should not be permitted to bury or otherwise dispose of the still-birth until an order for burial has been issued by the registrar.

"(10.) That, subject always to the discretion of the Crown Office, the result of precognitions taken by the Procurators Fiscal in Scotland or the precognitions themselves should be communicated to the representatives of the deceased when application is made for the same."

Improvements in Registration required. The preceding sketch of the system of registration now in force renders a detailed discussion of the defects of registration unnecessary. The recommendations of the Parliamentary Committee embody some of the more important improvements required. These do not include the appointment of medical chief registrars, though this is referred to favourably in their report. This reform would probably do more than anything else to improve our system of registration. As matters now stand, when there is no medical certificate of the cause of death, the registrar makes inquiries of the relatives of the deceased person, and if he is satisfied with their explanation of the cause of death, and has satisfied himself that there are no suspicious circumstances connected with the death, enters it according to their statements, adding that the death is "not medically certified."

Such a system is obviously open to the grossest abuse. All this would be remedied if, as Dr. Farr proposed in 1864, *medical registrars* were appointed, who should preferably be the medical officer of health of the district. It should be part of his duty to make a medical inquisition into the cause of death in all dubious cases. In Ireland medical men hold the position of registrars, and the evidence of Dr. Grimshaw, the Registrar-General of Ireland, appears to show that the causes of death are more correctly certified in Ireland than in other parts of the United Kingdom.

Use made of Information furnished by Registration. Weekly and quarterly returns are made by the local registrars to the Registrar-General, Somerset House, London. These are collated and abstracted; and from these abstracts the periodical reports issued from the General Register Office are prepared. The following are the chief of these reports:—

1. A Weekly Return of the births and deaths from all causes, and from the chief infectious diseases, in each of thirty-three great English towns, with similar particulars for the registration sub-districts of London, and meteorological and other data for the week. The Weekly Return also embodies important returns from a number of foreign cities.
2. A Quarterly Return of marriages, births, and deaths registered in the divisions, counties, and districts of England, with certain detailed information relating to the deaths in each registration sub-district.
3. An Annual Summary of the births, deaths, and causes of death in London, in the thirty-three great towns, and in sixty-seven other large towns, with an appendix on the metropolitan water-supply.
4. An Annual Report of births, deaths, and marriages in England, containing fuller particulars than the preceding reports, but dealing in detail with registration districts and sub-districts, not with towns, unless they happen to coincide with these.
5. A Decennial Supplement, containing *inter alia* life-tables representing the experience of England and of its healthy districts, and an important discussion of occupation in relation to mortality. These supplements contain some of the most important work of the General Register Office, and are invaluable for reference. The last one (for 1881–90), by Dr. Tatham, is indispensable to vital statisticians, and a worthy successor of the

earlier supplements by Drs. Farr and Ogle, which are classical contributions to the subject.

The student should make himself familiar with each of the above reports, as well as with the last General Census Report. It is only by this means that he can make full use of the mine of information that they contain. Although to some extent the different reports overlap, they are all necessary for the development of the full value of the vital statistics of England.

The weekly reports are issued on the Tuesday morning next following the end of the week to which they refer; the quarterly reports in the month following the end of the quarter; while the annual reports usually appear toward the end of the year subsequent to the year to which they apply. The annual summary, however, appears in April or May. In regard to the delay in the issue of the annual reports, Dr. Farr says: "They may be regarded as storehouses of facts, which have been arranged on methods that are approved as the most useful and convenient, and to which, both now and in future years, students of vital statistics may resort for the elucidation of questions bearing on the social condition of the people, on national progress, on life, health, and disease. It is important they should be *done well*. It is desirable only in the next degree that they should be *done quickly*."

The value of these various reports can scarcely be exaggerated. The rates of mortality in the weekly reports require, however, to be accepted with caution, as large fluctuations in short periods may be due to accidental causes. But in indicating the character and amount of prevalent diseases, and their geographical distribution, they are invaluable. As Farr eloquently puts it: "Thus observers, like watchmen on the walls, are ever on the look out, so that they can see exactly what is going on, and neither plague, cholera, nor any other great epidemic can take the nations by surprise. The deaths serve the purpose of a self-registering inspection. Death cannot be deceived by sham defences."

The regulations as to registration of deaths and burials in England may be contrasted with those in other countries by reference to Palmberg and Newsholme's *Treatise on Public Health*—England, p. 11; Brussels, p. 230 (system of verification of deaths); Paris, p. 279; Berlin, p. 377; Vienna, p. 418; Sweden, p. 441.

The Report of the Select Committee of the House of Commons on Death Certification also embodies some valuable international information, as well as fuller details on the whole subject, than can be given here.

CHAPTER IV.

DEATH CERTIFICATION AND CLASSIFICATION OF CAUSES OF DEATH.

THE **Registration of Causes of Death** has given an immense impetus to sanitary work, and it is scarcely too much to say that modern sanitary science owes its existence to the registration of deaths and their causes, and the localisation of insanitary conditions thereby insured. By its means, conjoined with the census returns, we are able to submit to numerical analysis the facts relating to the laws of vitality, the influence of age and sex, of civilization, occupation, locality, season, and many other agencies; and our knowledge of all the facts bearing on health and disease has attained a precision never before known.

There are certain **fallacies** in the registration of causes of death, partly owing to the imperfection of medical science and of a portion of its practitioners, and partly owing to differences of nomenclature and classification of diseases.

The deaths uncertified have been already considered. It is evident that as these gradually diminish there will be a transference to death under some definite head. The same applies to the mortality from ill-defined causes, the increased accuracy of diagnosis causing a steady decrease under this head. Thus in 1895 there were in England 25,762 deaths classed as from "*ill-defined and not specified causes,*" being 4·5 per cent. of the total deaths. In 1862 the death-rate in England and Wales per million living was 2104 under this head; in 1872 it was 1854; and in 1882 it was 1154, decreasing still further to 849 per million living in 1895.

The number in 1895 would have been greater had not 5255 answers been received to letters of inquiry concerning doubtful cases previously sent out from the Registrar-General's office (a system first started in 1881, when about 1200 letters of inquiry were sent to medical men, asking for further information than was given in their certificates.)*

Faulty diagnosis and the desire to shield relatives are perhaps the most prolific sources of inaccurate and indefinite certificates. In many cases the certified causes of death, *e.g.* cardiac syncope, as Dr. Rumsey long ago pointed out, are nothing more than *modes* of death. The most common headings found in this indefinite class are *abdominal disease*, *debility*, *atrophy*, *inanition*, *innutrition*, *wasting*, *congenital debility*, *cachexia*, *tumour*, *blood-poisoning*, *hæmorrhage*, *dropsy*, *convulsions*, etc.

Peritonitis standing alone is similarly unsatisfactory without its cause being defined, a large proportion of the cases being puerperal in origin.

In many parts of the country, especially in Wales, the causes of death stated by friends are very commonly accepted by the local registrar without any medical certificate. This probably explains in part the prevalence of *consumption* in Wales; any wasting disease, especially if accompanied by cough, being called by that name.

The mortality from "*abdominal disease*" is on the decrease, which accounts for a part of the registered increase in mortality from cancer in recent years.

The *lack of uniformity of nomenclature* among medical men is another source of fallacy. There appears to be a fashion even in the names of diseases. In one doctor's practice nearly all the deaths from respiratory diseases will be returned as bronchitis or congestion of the lungs, in another perhaps as pneumonia. It is necessary, therefore, in instituting comparisons for a series of years, to take preferably a well-marked and easily recognizable cause of death, or where this is impracticable, a large group of diseases in which the sources of fallacy tend to counterbalance each other.

In dealing with such causes of death as alcoholism, syphilis, and insanity, serious sources of statistical error arise; and the same remark applies to a variable extent to diseases affected by improvement in diagnosis and the still greater improvement in accuracy of certification, such as renal diseases, internal cancer, etc.

The official form of death certificate and the official suggestions to medical practitioners are here appended, and it is most desirable that the suggestions should be rigidly followed.

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* For particulars as to the results of these inquiries see p. 18, *Registrar-General's Annual Report*, 1895.

N.B.—PLEASE TO READ THE SUGGESTIONS ON PAGE ii.

Counterfoil for the use of the Medical Attendant, who should in all cases fill it up.

Name of Deceased ________

Age ________

Last seen ________

Died on ________

At ________

Cause of Death:—

(*a*) ________

(*b*) ________

Signed ________

Date ________

CERTIFICATE OF CAUSE OF DEATH.

London: Printed by Authority of the Registrar-General.

Not to be used by any other than a Registered Medical Practitioner.

BIRTHS AND DEATHS REGISTRATION ACT, 1874.

MEDICAL CERTIFICATE of the CAUSE of DEATH.

To be given by the Medical Attendant to the Person whose duty it is to give it, with information of the Death, to the Registrar of the SUB-DISTRICT in which the DEATH took place, and TO NO OTHER PERSON.

No. of corresponding Entry in Register Book of Deaths to be inserted here by the Registrar: ☐

I HEREBY CERTIFY *that I attended* ________ *during h* __ *last illness; that such Person's age was stated to be* ________ *; that I last saw h* __ *alive on the* ____ *day of* ____ *18* __ *; that he Died** ________ *on the* ____ *day of* ____ *18* __ *, at* ________ *and that to the best of my knowledge and belief the Cause of h* __ *death was as hereunder written.*

* Should the Medical Attendant not feel justified in taking upon himself the responsibility of certifying the *fact* of Death, he may here insert the words "*as I am informed.*"

† The duration of each form of Disease or Symptom is reckoned from its commencement until death occurs.

Cause of Death.	Duration † of Disease in			
	Years	Calendar Months	Days	Hours
Primary ________				
Secondary ________				
.... ________				

[The Informant should read the Instructions on the back of this Form.]

Witness my hand, this ____ *day of* ________ *18* __

Signature ________

Qualification as registered by Medical Council ________

Residence ________

N.B.—THIS CERTIFICATE IS INTENDED SOLELY FOR THE USE OF THE REGISTRAR, to whom it should be delivered by the Person giving information to him of the particulars required by law to be registered concerning the Death. *Penalty of £2 for neglect of Informant to deliver this Certificate to Registrar.* *** The Registrar-General *cautions all persons* against *accepting* or *using* this certificate for any purpose whatever except that of delivering it to the Registrar.

Suggestions to Medical Practitioners respecting

1. State the *Causes of Death* in terms as precise and brief as possible, and use the names adopted in the nomenclature of the Royal College of Physicians, taking the English names in preference to the Latin or other foreign equivalents. Vague terms such as *Decline*, *Tabes*, *Cachexia*, &c., should be *avoided*. So also *Hæmorrhage* should not be assigned as a Cause of Death without further specification of its *probable origin* and the *organ affected*. *Tetanus* again should be defined as *Idiopathic* or *Traumatic*, and if the latter the *cause and nature of the injury* should be added.

2. Write the Causes of Death, when there are more than one, under each other, *in the order of their appearance*, and not in the presumed order of their importance.

3. Medical Practitioners should not content themselves with assigning, as is too often done, some *prominent symptom* as the Cause of Death; but should state, whenever possible, *the disease to which the symptom was due*. Sometimes, doubtless, it will happen that the nature of the fatal disease cannot be ascertained with certainty; in such cases, and in such alone, a leading symptom should be assigned as the Cause of Death. "Dropsy" should not be returned as the Cause of Death without stating *whether the Dropsy was due to Heart Disease, or Renal Disease, or the like*; when "Dropsy" alone is returned, it is assumed that the cause of this symptom was not ascertained.

Similarly, when the immediate Cause of Death was dependent upon some general condition, such, for instance, as the Strumous, the Syphilitic, or the Rickety constitution, *this remoter Cause should be stated, as well as the more immediate Cause.*

4. In certifying Deaths from any form of Continued Fever, *state the kind of Fever*, and, in so doing, be especially careful to adopt the nomenclature of the College of Physicians. Avoid all such ambiguous terms as Low Fever, Miliary Fever, Brain Fever, Hectic Fever, Febrile Attack, &c. Similarly avoid the term "*Typhoid Pneumonia*," which may mean either Asthenic Pneumonia with typhoid symptoms, or Enteric Fever with secondary Pneumonia.

Do not use the term Infantile Remittent Fever for Enteric Fever in children.

5. When the Cause of Death has been verified by a *post-mortem* examination, the letters P.M. should be added.

6. State, in fatal cases of Small-pox, whether Vaccination had been performed with effect and when, or whether the deceased was unvaccinated. If possible, state the evidence of Vaccination, *e.g.*, "two bad marks." The term "Vaccinated" should be used in preference to "After Vaccination." "Small-pox after Vaccination, 21 days," is ambiguous, because the question arises whether the period (21 days) refers to the Small-pox or to the Vaccination; the Cause of Death should be certified as "Small-pox 21 days (vaccinated)."

7. Whenever *Child-birth* has occurred *within one month before death*, this

N.B.—NO MEDICAL PRACTITIONER IS JUSTIFIED IN GIVING A CERTIFICATE UNLESS

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[*] The above are the official suggestions prefacing the book of blank death-

Certificates of the Cause of Death.*

fact should invariably be certified, even though it may be believed that the Child-birth had no connection with the Cause of Death.

8. The *Duration* of primary and secondary diseases in these Certificates will always be considered to mean the time intervening between the first appearance of well-marked characteristic symptoms and death.

Small-pox, Scarlet Fever, Measles, and other similar febrile diseases should, however, be dated *from the rigors and first symptoms;* not from the later appearance of the eruption.

Ague, Epilepsy, Angina Pectoris, and other maladies that occur in fits or paroxysms, should be dated *from the first attack,* the duration of the last fit being added.

The duration should be stated in minutes or hours when the disease is fatal in less than 48 hours; in days when the disease is of less than 50 days' duration; in months or years when the disease is of still longer duration.

Examples:—(a)	Scarlet Fever	30 days
	Anasarca	7 days

Implies that the earliest symptoms of Scarlet Fever occurred 30 days before death, and that Anasarca was first noticed 7 days before death.

(b)	Epilepsy	5 years
	Last Fit	6 hours

Implies that the first Epileptic fit occurred five years back, and that the fatal fit lasted 6 hours.

(c)	Excessive use of Spirits	——
	Delirium Tremens	6 days

Implies that the deceased had been for an unknown time given to intemperance, and suffered from Delirium Tremens for 6 days before death.

9. SURGEONS in all cases of operation should return (a) the primary disease or injury; (b) the kind of operation; (c) the secondary diseases—such as Erysipelas, Purulent Deposits, &c., and should state also the time from commencement of the primary disease, the time from the operation, and the time from the appearance of secondary disease, *reckoning in each instance to the death.*

Examples:—

Femoral Hernia	3 years
Strangulated	5 days
Operation	2 days
Peritonitis	45 hours

10. In every case of Death from violence, or suspected violence, the Medical Practitioner should advise the friends of the deceased to bring the case to the knowledge of the Coroner in order that he may decide as to holding or not holding an Inquest, inasmuch as the Coroner may otherwise feel it his duty, when the case comes to his knowledge, to order the body to be exhumed and inquiry instituted.

HE WAS PERSONALLY IN ATTENDANCE UPON THE DECEASED DURING THE LAST ILLNESS.
certificates, obtainable by any qualified practitioner from the registrar.

Nomenclature of Diseases. The necessity of uniformity is obvious, as otherwise any classified results must be untrustworthy. The nomenclature of the Royal College of Physicians of London, of which the third edition, being the second revision, appeared in 1896, is the standard adopted in all English-speaking countries, and all death returns should be made in accordance with this. Of course no classification will obviate the differences due to the opinions of individual practitioners, as, for instance, the return by one practitioner of death as due to croup which another would certify as diphtheria. [See Postscript, p. 346.]

The preface to the first edition of the Royal College of Physicians' classification contains many weighty remarks bearing on this question of **Nomenclature and Classification,** which are here summarised. It is pointed out that the great ends of such a nomenclature are (1) to perfect the statistical registration of diseases, (2) to form a steady basis on which medical experience can be built up, and (3) to throw light on the causes of disease, which, in many cases, may thus be brought within the range of preventibility.

The committee appointed by the Royal College of Physicians expressed their sense of the desirability of as little deviation as possible from the list of names employed by the Registrar-General of England; as otherwise his settled plans and his forms of returns would require to be remodelled, the comparison of future with past returns would be made difficult and perplexing, if not impossible, and a damaging break would be caused in evidence which becomes more and more trustworthy and valuable in proportion as it is prolonged and continuous.

They also refused to exclude names, such as dropsy, palsy, convulsions, merely because they may seem to express only vague or imperfect knowledge, agreeing with Dr. Farr that the refusal to sanction such terms as these in the region of disease "would have an obvious tendency to encourage reckless conjecture" in making returns. The Revision Committee (1885), however, while fully acknowledging the wisdom of the above remark, "felt it right to indicate as strongly as possible the necessity of avoiding the use of the names of symptoms wherever the names of diseases or of causes of symptoms could with reasonable certainty be substituted." Thus the term apoplexy should only be used when the morbid condition causing it cannot be recognized.

The classification of diseases is a more difficult task than their nomenclature, and it is pointed out that the comparison of single diseases (*if well marked*) is more reliable than that of groups of diseases. But although a good classification is very difficult, it is very important, as it "aids and simplifies the registration of diseases, helps towards a more easy comparison and knowledge of them, and towards the storing of experience respecting them, and facilitates the discovering of general principles from the collected, grouped, and compared phenomena."

A classification might be according to (1) symptoms, (2) causes, (3) intimate nature, (4) tissues or systems of the body affected, (5) parts of the body as they lie anatomically. The committee based their classification on anatomical considerations, and in subservience to this grouped diseases as General and Local. General diseases were divided into section A, comprehending those disorders which appear to involve a morbid condition of the blood, such as the specific fevers; and section B, comprising for the most part disorders which are apt to invade different parts of the same body simultaneously or successively, sometimes called Constitutional Diseases. The Revision Committee, in the second edition, pointed out that the name General Diseases fails to express the nature of the group which it heads, and that *Morbi Corporis Universi* would convey more clearly the idea intended, or "Diseases of the whole body and diseases which may be distributed in several parts at one time,—General Diseases." In the third edition the term "General Diseases" is restored, and is used to include not only diseases properly so called, but morbid conditions affecting either the whole body or more than one part.

The system of classification of diseases must *vary according to the object* of the registration. Thus (1) the Registrar-General tabulates deaths and the causes of death. His is essentially a classification based on an etiological basis, and thus possesses a supreme importance from a hygienic standpoint. The College of Physicians' classification is one of diseases, while that of the Registrar-General is of assigned causes of death; one is pathological, the other etiological. This is seen very strikingly in the classification of injuries, the College of Physicians classifying them according to their position and nature, while the Registrar-General divides them into accidental, homicidal, suicidal, and execution.*

(2) The army and navy medical departments tabulate diseases

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* Similarly cases of whooping-cough with death from pneumonia are referred by the Registrar-General to the former and much more remote cause of death. Most classifications which give a single cause of death in their ultimate analysis would ascribe the death to pneumonia.

as well as deaths occurring in the two services. Hence many diseases appear which are not seen in the death returns.

(3) The registrars of hospitals and the medical officers of infirmaries deal mainly in their returns with the distribution of morbid processes within the body, and seek rather to find the proportion of deaths to attacks than the proportion of number of attacks or deaths to population. As this method takes note of ultimate and proximate causes of deaths, stating the original disease and its complications, there is commonly for each individual disease a multiple return.

It is evident, therefore, that there must co-exist two dissimilar methods of classification, of which the etiological is for our present purposes by far the most important.

We must repeat that the knowledge of a well-marked single disease is safer for comparative purposes than that of a group of diseases. For instance, the term Zymotic Diseases includes enteric fever and whooping-cough, which have a very unequal value as a test of the sanitary condition of any locality. In regard to constitutional diseases, it should be remembered also that certain diseases, such as contracted granular kidney, which are classed under local diseases, might perhaps more justly come under the head of constitutional diseases, while in other instances the converse holds good.

The Registrar-General's classification can be seen by reference to his annual reports, *e.g.*, report for 1895, p. 52 *et seq.* This classification is employed almost solely in the annual reports of medical officers of health. A glance down the list of diseases shows that in certain minor particulars it is not abreast with medical knowledge. Thus tubercular diseases, and almost certainly rheumatic fever, should be transferred from constitutional to infective diseases, and tetanus to the same group from diseases of the nervous system. Fatal croup again in the vast majority of cases means diphtheria, and probably the same remark applies to quinsy. These two diseases were formerly placed by the Registrar-General next to diphtheria, and were relegated to their present position among diseases of the respiratory and digestive system respectively, in deference to the classification of the Royal College of Physicians.

For illustrations of statistical tables useful in the compilation of the annual report of a medical officer of health, see Palmberg and Newsholme's ***Treatise on Public Health and its Applications in Different European Countries***, p. 12 *et seq.*

CHAPTER V.

REGISTRATION OF SICKNESS.

THE registration of deaths gives a very imperfect view of the prevalence of disease. The medical officer of health would have a greatly increased power of protecting the public health if he could by early information of every case of preventible disease track its development and progress, and adopt measures of prevention. Dr. Lyon Playfair in 1874 emphasized the importance of registration of sickness in these words: "The record of deaths only registers, as it were, the wrecks which strew the shore, but it gives no account of the vessels which were tossed in the billows of sickness, strained and maimed as they often are by the effects of recurrent storms. Registration of sickness would tell us of the coming storms, and enable us to trim our vessels to meet them."

Mortality statistics necessarily "ignore all that precedes the close of life." The prevalence of a given disease cannot be gauged with absolute accuracy in the absence of registration of each case of the disease, except when, as in hydrophobia, the disease is always fatal.

It is fallacious to assume any fixed ratio between sickness and mortality. The *fatality of a given infectious disease varies greatly* in different outbreaks under varying circumstances. The highest ratio of sickness is occasionally found associated with a favourable rate of mortality. Cholera is much less fatal towards the end of an epidemic than at its beginning; so a conclusion drawn simply from the death returns might easily exaggerate the diminution in the prevalence of the disease. There are some diseases, again, the knowledge of which is desirable, but which do not perceptibly affect the mortality (except in some cases, through secondary consequences), as quinsy, mumps, chicken-pox, gonorrhœa.

The medical officer of health, who only knows of fatal cases of preventible diseases, is to a large extent in the impotent position of a mere recorder of events. If he knew of *every* case, preventive measures could be adopted at an early stage, and the outbreak could be tracked to its true origin, as not a single link in the chain of evidence would be missing.

Death returns are silent about the large mass of common sickness, which, although it may disable a man, is not "unto death." From an economical point of view this *sickness is more important than deaths*, "for it is the amount and duration of sickness rather than the mortality that tell on the prosperity of a community." (Dr. Dickson.) Or as Charles Dickens has stated it: "It concerns a man more to know his risks of the fifty illnesses that may throw him on his back than the possible date of the one death that must come. We must have a list of killed *and of the wounded too!*"

Local returns of disabling sickness of every description would not only enable us to deal promptly with epidemic disease, but would also throw great light on the influence of season and climate, of social condition, and of trades and manufactures on health, and would thus enable preventive measures of diverse kinds to be brought into action.

It is evident that even were it possible it is not requisite to know of every case of sickness. The lines of demarcation between health and sickness are ill-defined, and it would be necessary to limit the returns to disabling sickness.

Attempts made to Register Sickness. We cannot attempt here to give a history of the various attempts made in this country to obtain registration of prevalent diseases by B. W. Richardson, Rumsey, and others. Two organized efforts which were for some time successful may be briefly mentioned.*

The first was made by the Metropolitan Association of Health Officers in 1857, and included sickness of all kinds attended at the public expense, in hospitals, and by poor law medical officers, dispensaries, workhouses, etc. The returns were contributed gratuitously by the respective medical officers, the general Board of Health undertaking to print and circulate the weekly and quarterly tables. Of 109 hospitals and dispensaries generally less than 50 contributed; in some cases boards of guardians refused to supply information; and before the expiration of the second year the tables, which had never been complete for all sickness attended at the public expense, ceased to appear, voluntary co-operation being evidently unequal to the enterprise. It should be noted also that the returns were not entirely trustworthy so far as they went, for the diseases and accidents notified were not all new cases; that many returns represented patients who had come up from country districts for hospital treatment; and that an indefinite number of patients, who wander from hospital to hospital, must have been notified more than once. Dr. Ransome and the Sanitary Association of Manchester and Salford organized in 1860 a system of registration of sickness for these towns which appears to have been very complete and exact, and was not finally abandoned until the compulsory notification of infectious diseases came into force nearly twenty-five years later. An attempt was made, at Dr. Ransome's suggestion, to obtain simultaneously with the returns of disease a record of the mortality occurring amongst the cases reported. This was then compared with the total mortality, and a very fair guess could thus be made as to the total number of cases occurring within the district.

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* For fuller particulars of the history of notification of sickness see a paper by the author on "A National System of Notification and Registration of Sickness," *Jour. Statist. Soc.*, vol. lix. part i., 1896.

The **Requirements of a Plan** for the registration of disease have been set forth by Dr. Farr as follows, in the supplement to the Registrar-General's Thirty-fifth Annual Report: "The reports of the existing medical officers are of great practical value, and will become more valuable every day. What is wanted is a staff officer in every county or great city, with clerks to enable him to analyse and publish the results of weekly returns of sickness to be procured from every district; distinguishing, as the army returns do, the new cases, the recoveries, the deaths reported weekly, and the patients remaining in the several hospitals, dispensaries, and workhouses. These compiled on a uniform plan, when consolidated in the metropolis, would be of national concern. It has been suggested that the returns of sickness should, to save time, be sent to London, and there analysed on a uniform system as the causes of death are. That with the present postal arrangements is quite practicable. The thing to aim at ultimately is a return of the cases of sickness in the civil population as complete as is now procured from the army in England. It will be an invaluable contribution to therapeutics, as well as to hygiene, for it will enable the therapeutists to determine the duration and the fatality of all forms of disease under the several existing systems of treatment in the various sanitary and social conditions of the people. Illusion will be dispelled, quackery, as completely as astrology, suppressed, a science of therapeutics created, suffering diminished, life shielded from many dangers. The national returns of cases and of causes of death will be an arsenal which the genius of English healers cannot fail to turn to account."

Information Available. Apart from compulsory notification of infectious diseases, the following sources of information are available:—

1. Under an order made by the Local Government Board in February, 1879, it is incumbent on all district and workhouse medical officers appointed since that date to furnish the medical officers of health with returns of pauper sickness and deaths, as well as to notify the outbreak of dangerous infectious disease. A similar obligation has been imposed upon medical officers of district schools appointed after June, 1879. By means of these returns of pauper sickness a fair estimate of the prevalence of disease among the poorest classes can be obtained.

2. The keeper of a common lodging-house is bound to give information to the local authority of any case of dangerous infectious disease occurring on his premises.

3. Where bye-laws are in force in any district in relation to houses occupied by more than one family, the householder may be compelled to notify the occurrence of infectious disease to the local authority.

4. In addition to these sources of compulsory information, information is usually available from medical men where disinfection or removal of patients is required, from the clergy, from school-board officers, and from the post-office authorities when any of their employees suffer from infectious illness.

It is unfortunate that in the stress of modern political life the subject of a national system of notification and registration of sickness, except as regards the chief infectious diseases and certain industrial diseases, has been allowed to drop into abeyance. The compulsory notification of infectious diseases will be considered in the next chapter.

What may be regarded as an ideal system is that in force in the army and navy, where every case of sickness is tabulated as to character, duration, and result. Such a complete system is impracticable in civil life, and we will content ourselves with a series of proposals of what may be reasonably attempted so far as the general population is concerned. This necessitates a short previous discussion of the **scope of preventive medicine.**

To contend that preventive medicine is limited in its scope by the so-called zymotic diseases, is to rob it of its most important and promising field of work. Zymotic diseases * in the five years 1891–95 caused an average annual death-rate of 2757 per million living. In the same period rheumatic fever and rheumatism of the heart were responsible for an average death-rate of 88 per million; endocarditis and pericarditis, which in a vast preponderance of cases are caused by rheumatism, causing a death-rate of 333 per million; while tubercular diseases caused a death-rate of 2123 per million (phthisis being responsible for 1464 of this); and bronchitis and pneumonia caused a death-rate of 3329 per million. Of the zymotic diseases a death-rate of 806 per million was caused by measles and whooping-cough collectively, of 415 per million by influenza, and of 652 per million by diarrhœa and cholera. None of these is included in the scope of compulsory notification of infectious diseases as enforced in the majority of districts; and although it may be doubted whether any immediate practical benefit would arise from such notification, the improved knowledge of their natural history and causation, which would gradually accumulate, must in the end prepare the way for more effective preventive measures. At present, with the possible exception of summer diarrhœa, it may be said of these diseases that the sanitary measures already adopted in this country have produced but little, if any, effect. If we omit these diseases, there remains a death-rate of 884 per million due to infectious diseases, the spread of some of which has been seriously combated by sanitary authorities. The total annihilation of the latter diseases would only have reduced the general death-rate, in 1891–95, from 18·74 to 17·86 per 1000; while the annihilation of tubercular diseases, which is much more within the range of possibility, and may in fact be accomplished, like the already secured annihilation as an endemic disease of the closely allied disease leprosy in this country, would have reduced the general death-rate in 1891–95 from 18·74 to 16·62 per 1000. The mortality really caused by rheumatic fever and its sequelæ is immensely understated by the 421 per million officially ascribed to rheumatic fever, endocarditis, and pericarditis. This disease will probably ere long come into the list of actively preventible diseases. A very large amount of bronchitis and pneumonia is caused by improper conditions of housing or of work; and there is little doubt that a large saving might be effected under this head. Alcoholism figures low in the official returns, 68 deaths per million being ascribed to this cause in 1891–95; and even if we add the death-rate of 120 per million caused by cirrhosis of the liver (an almost entirely alcoholic disease), the official returns give a very incomplete notion of the immense mortality due to this preventible cause. These instances by no means exhaust the list which might be given to illustrate the fact that preventive medicine is concerned with all the diseases to which flesh is heir, the only condition beyond its possible scope being old age.

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* Including small-pox, measles, scarlet fever, typhus, enteric and continued fever, whooping-cough, influenza, cholera, diarrhœa, malaria, hydrophobia and other zoogenous diseases, venereal diseases, erysipelas, puerperal fever, and other septic diseases.

Proposals as to National Notification and Registration of Sickness. Accurate knowledge of sickness, of its degree of incidence in relation to sex, age, occupation, housing, locality—in fact of all the conditions under which it is originated—must precede rational preventive measures. Hence it is necessary that the following measures should be adopted:—

1. *All cases of sickness occurring among the parochial poor* in each district should be periodically reported to the medical officer of health, and tabulated statements concerning them forwarded to a central office in London, in which such statistics, along with those from other sources, should be analysed, summarized, and published.

Schedules might easily be arranged similar to those in force in Christiania or Berlin, in which a weekly return of the new cases of sickness among the poor could be made by the Poor-Law medical officer with a minimum of trouble. The cases in the workhouse infirmaries and in industrial schools should be similarly scheduled. Care would be required to prevent the same cases from being entered more than once. The machinery necessary for the carrying out of this proposal already almost completely exists. (See p. 40.)

2. *All cases of sickness, whether out-patients or in-patients, at*

hospitals (general and special) and at public dispensaries should be reported weekly to the medical officer of health, and a summary forwarded by him to the central office in London, to be there treated like the pauper statistics. The hospitals and dispensaries of this country are supported by subscriptions or bequests; and it would, I think, be reasonable to require that every public institution for the treatment of the sick should give to the medical officer of health a weekly statement of the number of new in-patients and out-patients treated during the week, specifying the age, sex, and nature of the illness of patients; also a quarterly or annual statement of the total cases, and the number of days spent by each patient in the hospital. The statistics of large general hospitals, especially those to which medical schools are attached, are of great value, the diagnosis and certification being exceptionally accurate. These statistics possess a high value in the study of the annual and seasonal incidence of diseases like rheumatic fever, as I have shown in the Milroy Lectures for 1895.*

It is particularly unfortunate that in so many hospitals classified records of cases have not been regularly kept.

It should be made obligatory on the managing bodies of all general and special hospitals, and all public dispensaries, to keep accurate entries of all cases treated at these institutions, as well as to report on special schedules these cases to the medical officer of health at stated intervals. This has been done in Germany since 1877.†

Many important problems as to the intensity of different epidemics, the relative fatality of cases occurring in different districts, the influence of "hospitalism" on the character of each disease, etc., might be solved by accurate comparative statistics for the great fever hospitals throughout the country. At present there are statistical reports for such hospitals in the annual reports of some medical officers of health, of very varying comprehensiveness and value. What is required is that these should be collated on a uniform basis, and that the statistics from different hospitals should be analysed and published at a central office in London.

The annual reports of the Statistical Committee of the Metropolitan Asylums Board, the report for the year 1896 being the eleventh of the series, form in some respects a model for others.

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* *The Lancet*, March, 1895.

† For particulars see my paper in the *Royal Statist. Soc. Jour.*, vol. lix. part. i. p. 16.

3. *All Friendly Societies, and all sickness insurance societies of every description* should be required to furnish weekly or monthly returns of the number of new cases of sickness in their experience, classified according to a specified schedule, and a yearly statement of the total number of subscribing members, classified according to age.

Such Friendly Societies are already under some degree of control as regards their financial condition, and accurate statistics of sickness might be required in the interest of the community. These would furnish a very valuable means of estimating the relative amount of yearly sickness at different ages in the industrial classes, the relative incidence of special diseases at certain ages and in special occupations, and so on. Such statistics would throw a flood of light on the healthiness or the reverse of various industries, and would open the way for valuable preventive measures.*

4. *An attempt should be made to obtain accurate returns of sickness in the great industries.* This can only be gradually secured. Two factors are necessary in order that industrial sickness may be estimated for comparative purposes: (*a*) an accurate return of the number of men employed in each industry; and (*b*) a similarly accurate return of the cases and causes of sickness; each classified according to age. Some important steps have been taken in this direction in the Factory and Workshops Act, 1895. By sec. 34 it is required that—

> The occupier of every factory and workshop shall, on or before the 1st day of March in every year, send to the inspector of the district on behalf of the Secretary of State a correct return specifying, with respect to the year ending on the preceding 31st day of December, the number of persons employed in the factory or workshop, with such particulars as to the age and sex of the persons employed as the Secretary of State may direct, and in default of complying with this section shall be liable to a fine not exceeding £10.

There is no provision requiring a general notification of sickness among the employees, although this would be quite practicable.

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* It is true that at present there is great discrepancy in the administration of Friendly Societies and in the amount of sickness which their experience shows in persons of corresponding ages. The data from these societies would consequently require to be judiciously employed for many years to come. The proposed collation and tabulation and publication of the experience of these societies would, however, probably form the first step in the direction of securing more uniform administration of sick relief in different localities.

The only approach to it are the enactments contained in sec. 20 and sec. 29.

Sec. 20 states that—

(1.) Every occupier of a factory or workshop shall keep a register of accidents, and shall enter therein every accident occurring in the factory or workshop, of which notice is required by the Factory Acts within one week after the occurrence of the accident, and this register shall be at all times open to inspection by the inspector and the certifying surgeon for the district.

(2.) If any occupier of a factory or workshop makes default in complying with the requirements of this section, he shall be liable on summary conviction to a penalty not exceeding £10.

This enactment will doubtless be of great value in determining the relative liability to accidents of different industries, and the directions in which additional regulations and restrictions are required.

Sec. 29 requires that—

(1.) Every medical practitioner attending on or called in to visit a patient whom he believes to be suffering from lead, phosphorus, or arsenical poisoning, or anthrax, contracted in any factory or workshop, shall (unless the notice required by this section has previously been sent) send to the Chief Inspector of Factories at the Home Office, London, a notice stating the name and full postal address of the patient, and the disease from which, in the opinion of the medical practitioner, the patient is suffering, and shall be entitled in respect of every notice sent in pursuance of this section to a fee of 2*s.* 6*d.*, to be paid as part of the expenses incurred by the Secretary of State in the execution of the principal Act.

(2.) If any medical practitioner, when required by this section to send a notice, fails forthwith to send the same, he shall be liable to a fine not exceeding 40*s.*

(3.) Written notice of every case of lead, phosphorus, or arsenical poisoning, or anthrax, occurring in a factory or workshop, shall forthwith be sent to the inspector and to the certifying surgeon for the district; and the provisions of the Factory Acts with respect to accidents shall apply to any such case in like manner as to any such accident as is in those sections mentioned.

(4.) The Secretary of State may by order made in accordance with sec. 65 of the principal Act apply the provisions of this section to any other disease occurring in a factory or a workshop, and thereupon this section and the provisions referred to therein shall apply accordingly.

The provisions in sec. 29 constituted at the time they were enacted a new and evil departure, that of compulsory notification of disease by a medical practitioner to a layman,* implying, in part at least, the investigation of the medical problems of the causation of special diseases by lay inspectors. The objection has since been diminished by the appointment of Dr. Whitelegge as H.M. Chief Inspector of Factories, and later by the appointment of Dr. Legge as Medical Inspector of Factories. There can be little doubt that as more attention is paid to the important subject of industrial hygiene it will be necessary to arrange for the local medical officer of health to receive in the first instance the notifications under sec. 29, and conduct the primary inquiries arising out of these. The transfer of control of Bakehouses from the central to local authorities is a somewhat analogous case.

To sum up:—

(*a.*) All cases of sickness treated at the expense of public funds, whether in connection with the administration of the Poor Law (out-door infirmaries, industrial schools, etc.) or in isolation hospitals, or in idiot and lunatic asylums, should be periodically notified to the medical officer of health.

(*b.*) All cases of sickness treated by means of public charity, whether in general or special hospitals or dispensaries, should be similarly notified.

(*c.*) All cases of sickness treated in Friendly Societies or other sickness assurance societies should be similarly notified.

(*d.*) Returns of accidents and of certain diseases, as lead poisoning, woolsorters' disease, etc., or other industrial diseases, should be made part of a wider system of notification of diseases by private medical practitioners to the medical officer of health of each district.

(*e.*) All notifications of sickness should be sent in the first instance to the medical officer of health of each district, and by him transmitted to a central office in London.

(*f.*) The central office in London should probably be in connection with the General Register Office, Somerset House, and weekly returns of sickness should be published alongside of the weekly returns of mortality.

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* For further particulars on this point see communications from Dr. J. B. Russell of Glasgow, and from the author in the *British Medical Journal*, 31st August and 10th September, 1895.

CHAPTER VI.

THE COMPULSORY NOTIFICATION OF INFECTIOUS DISEASES.

THE primary object of registration of sickness is prophylactic, and from this standpoint the registration of infectious diseases is supremely important. Such registration, in order to be of value, must be *compulsory*. Whenever it has been simply voluntary and optional the returns have been invariably imperfect and incomplete. Voluntary notification has been tried in a few places, medical men being paid a fee for every case information of which they furnish to the sanitary authority. The result has been only very partial. The medical practitioner is by possibility subjected to odium and accused of a breach of professional secrecy when he notifies, unless the notification is compulsory. Such partial information is not trustworthy as indicating the prevalence of a disease, though it is better than none; nor is it so efficacious in stopping the spread of disease. The more cases the medical officer of health knows of, and the wider the basis on which his etiological inductions can be framed, the more likely are preventive measures to be successful. It must not be supposed, however, that compulsory notification of infectious diseases forms a complete means of meeting and combating infectious diseases. "We do not only seek to suppress them when they arise, but to prevent their origin" (Ransome), and to this end we require to study thoroughly their natural history, their habitats, and the conditions under which they develop and recur.

The notification of infectious diseases became actual fact in a characteristically British fashion. The experiment was allowed to be made by those towns desiring to make it. In September, 1877, the first local Act for enforcing the compulsory notification of the chief infectious diseases came into operation in Bolton, Lancashire. This example was followed by other towns, and the adoptive enactment of the Infectious Diseases (Notification) Act in 1889 was followed by a rapid adoption of the Act by urban and rural sanitary authorities throughout England. At the present time the Act applies to more than five-sixths of the English population, and there is little doubt that it will shortly be made compulsory throughout the whole of Great Britain.

In some of the earlier local Acts notification was (*a*) compulsory only on the householder (Greenock); (*b*) compulsory only on the medical attendant (*e.g.*, Manchester, Preston, Edinburgh, Aberdeen); while in three towns (Bradford, Norwich, and Nottingham) (*c*) it was made compulsory on the medical attendant to furnish a certificate of the disease to the householder, the latter being responsible for its transmission to the local authority. In most of the towns possessing local Acts the parent or occupier of the house is bound to give notice to the local authority in case no medical man is in attendance.

Provisions of the Infectious Disease (Notification) Act, 1889.

Adoption of the Act. This is a permissive or adoptive Act, which may be adopted by any sanitary authority by a resolution passed at a meeting of the authority after fourteen clear days' notice (sec. 5). In London alone it became immediately compulsory without any option, being replaced in the metropolis at the beginning of 1892 by similar enactments in the Public Health (London) Act, 1891.

Definition of Infectious Disease. The expression "infectious disease" applies to the diseases enumerated in the certificate on page 50, and any other infectious diseases to which this Act has been applied as provided under sec. 7 (sec. 6).*

Extension of Act to other Infectious Diseases. Any local authority may, after fourteen days' notice given as the result of a special resolution passed by the authority at a previous meeting—as in the original adoption of the Act—order that the Act shall apply to any other infectious disease than those enumerated under sec. 6 [sec. 7 (1)]. Any such order may be permanent or temporary, the period to be specified in the latter case. The order under this section and the revocation or any variation of this order shall not be valid until approved by the Local Government Board [sec. 7 (2) and (3)]. In the case of emergency three clear days' notice under sec. 7 shall be sufficient, but the resolution of the local authority shall declare the cause of such emergency and shall be for a temporary order [sec. 7 (6)].

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* No definition is given of puerperal fever, and as according to the last edition of the *Nomenclature of Diseases* (1896, p. 11) the term "puerperal fever" should no longer be used, some latitude must be exercised as to what comes properly under this name. The *Nomenclature* adds "pyaemia, septicaemia, or sapraemia, occurring in puerperal women should be described as 'puerperal pyaemia,' 'septicaemia,' or 'sapraemia,' respectively." A Committee of the Royal College of Physicians of London has reported (Dec., 1898) that with a view to the limitation of dangerous infectious diseases the London County Council would be acting rightly in adopting the view that the expression "puerperal fever" should be taken to include septicaemia, pyaemia, septic peritonitis, septic metritis, and other acute septic inflammations in the pelvis occurring as the direct result of child-birth.

Notice of Adoption. Public notice must be given of the adoption of the Act and of all modifications of it, and every registered practitioner residing or practising within the district must receive a copy of such notice [sec. 5 (2) and sec. 7 (5)].

Method of Notification. Where an inmate of any building used for human habitation within a district to which this Act extends is suffering from an infectious disease to which this Act applies, then, unless such building is a hospital in which persons suffering from an infectious disease are received, the following provisions shall have effect:—

(*a*) The head of the family to which the patient belongs, and in his default the nearest relatives of the patient in the building or in attendance on the patient, and in default of such relatives every person in charge of, or in attendance on, the patient, and in default of any such person the occupier of the building, shall, as soon as he becomes aware that the patient is suffering from an infectious disease to which this Act applies, send notice thereof to the medical officer of health of the district.

(*b*) Every medical practitioner attending on, or called in to visit the patient, shall forthwith, on becoming aware that the patient is suffering from an infectious disease to which this Act applies, send to the medical officer of health for the district a certificate stating the name of the patient, the situation of the building, and the infectious disease from which, in the opinion of such medical practitioner, the patient is suffering.

Every person not complying with the above requirements is liable, on conviction, to a fine not exceeding 40*s.*; provided that if a person is required as above to notify only in default of some other person, he shall not be liable to any fine if he satisfies the Court that he had reasonable cause to suppose that the notice had been duly given.

Remuneration for Notification. The Local Government Board may from time to time prescribe forms for the purpose of certificates under this Act, and these forms must be used in certifying cases [sec. 4 (1)].

The following is the form at present prescribed:—

THE INFECTIOUS DISEASE (NOTIFICATION) ACT, 1889.

CERTIFICATE OF MEDICAL PRACTITIONER.

To the Medical Officer of Health.

I hereby certify and declare that in my opinion (1)..

.... *an inmate of (2)* ....

is suffering from (3) ....

Dated the.......................... *day of* .... 189......

Signed..

Medical Practitioner.

(1) Name in full of Person suffering from disease.

(2) No. or name of the house, and name of the street or road and parish or place where person is resident. In the case of a ship, boat, tent, van, shed, or other similar structure, the name or description of the dwelling, and the name of the place where it is situate should be given.

(3) Name of disease.

N.B.—This Certificate must (under a penalty not exceeding forty shillings) be sent to the Medical Officer of Health **forthwith** on the Medical Practitioner attending on or called in to visit the Patient becoming aware that the Patient is suffering from an infectious disease to which the Act applies; namely, any of the following diseases: Small-pox, cholera, diphtheria, membranous croup, erysipelas, the disease known as scarlatina or scarlet fever, and the fevers known by any of the following names: typhus, typhoid, enteric, relapsing, continued or puerperal, and also any infectious disease to which the Act has been applied by the Local Authority in manner provided by the Act.

The local authority is required to supply these forms to medical practitioners, and to pay to every medical practitioner for each certificate duly sent by him in accordance with this Act a fee of 2*s.* 6*d.* if the case occurs in his private practice, and of 1*s.* if the case occurs in his practice as medical officer of any public body or institution [sec. 4 (2)].

These certificates may be sent by being left at the office or residence of the medical officer of health, or may be sent by post addressed to him [sec. 8 (2)].

Exemptions under the Act. The provisions of this Act apply to every ship, boat, tent, shed, etc., used for human habitation [sec. 13 (1)], except ships and boats belonging to any foreign government. All buildings, vessels, tents, etc., belonging to H.M. the Queen are exempt from the terms of this Act (sec. 15).

Notification under the Public Health (London) Act, 1891. The chief regulations are identical with those of the Infectious Disease (Notification) Act, with the following exceptions :—

The medical practitioner is required to certify the age and sex of the patient and whether the case has occurred in private or public practice, as well as the usual particulars [sec. 55 (1) (*b*)].

The medical officer of health must, within twelve hours of the receipt of a notification certificate relating to a metropolitan patient, send a copy thereof to

(*a*) The Metropolitan Asylum Managers;

(*b*) The head teacher of the school attended by the patient if a child, or by any child who is an inmate of the same house as the patient [sec. 55 (4)].

Advantages of Compulsory Notification. The prompt and complete information furnished by this means

(*a*) Enables the medical officer of health to take immediate measures to prevent the spread of infection; by enforcing proper isolation of patients at home or in an isolation hospital; by enforcing efficient disinfection of infected articles and persons, including proper methods of disposal of the infected dead; by vaccinating those who have been exposed to the infection of small-pox; and by preventing the attendance of children in school or of adults in workshops from infected houses.

(*b*) It further enables the cause of an outbreak of an infectious disease to be investigated with a good chance of success. In its absence many of the links of evidence are missing. Thus the influence of water-supply, milk, or any other infected food-supply, of personal infection in school, workshop, laundry, etc., can be ascertained, and the influence of sanitary conditions of special localities or houses can be investigated.

(*c*) Not the least value of notification consists in the educational effect of the necessary inspections upon parents, householders, teachers, etc., and its still greater educational effect upon the members of local authorities. The constant reiteration of the lesson taught by the notification certificates has gradually and increasingly stimulated local authorities in the discharge of their duties. Hence it is not surprising to find that at no previous period of the sanitary history of England has there been such great activity as since 1889 in the provision of isolation hospitals. If these isolation hospitals had not, by the removal of first cases of infectious diseases in houses, diminished the prevalence of infectious diseases, they have as humanitarian institutions justified their existence by the better and more successful treatment that the majority of patients thus removed have secured; but they have also diminished the actual amount of some of these diseases. Small-pox epidemics are more easily manageable, and have been kept within narrower bounds in communities in which all cases are notified and isolation enforced. A portion of the greatly diminished fatality of scarlet fever is ascribable to the fact that patients are treated in a much higher proportion in large, airy, hospital wards, instead of in crowded houses with imperfect nursing.

(*d*) Even if it could be shown that compulsory notification of infectious diseases had not prevented radiation of disease from a single focus of infection, and had not led to the discovery of a single evil condition competent to produce further disease, the continued operation of the Act would be desirable from a wider standpoint. We are, by means of notification, gradually accumulating throughout the country a mass of information as to the seasonal, annual, epidemic, and cyclical prevalence of the chief infectious diseases such as has never previously been possessed by epidemiologists. As the first condition of success in the prevention of disease is knowledge of its natural history—its epidemicity, its relation to age and sex, to social and industrial conditions, to the complex meteorological conditions embodied in the words "season and climate"—such an accumulation of information must ere long bear fruit of a practical, useful character. Medical officers of health are not mere empiricists, concerned with the enforcement of general cleanliness, and of disinfection and isolation when cases of infectious disease arise. They are concerned not solely with individual cases of disease, but also with the conditions producing and controlling entire epidemics. It is in this branch of their work that knowledge is as yet most imperfect; and it is only by the accumulation of accurate and complete information as to each epidemic and inter-epidemic period, and by the collateral study of the personal and environmental conditions associated with these periods, that we can hope to arrive at a less empirical and more rational conception of the causation of each infectious disease, and through that of its prevention.

Effect of Notification on Zymotic Mortality. Attempts have been made to determine by appeal to figures whether compulsory notification diminishes the prevalence and fatality of infectious diseases. We doubt whether such an appeal to figures can be trusted, because it is hardly possible that the periods compared should fulfil an indispensable condition when comparisons are instituted; viz., that *other things shall be equal.* Notification is but a means to an end. In some towns the information furnished by it has been made the basis of active and persistent preventive work, while in others this has not been so. The question is mixed up also with that of hospital accommodation and isolation. There may be no immediate good results from notification if the patients notified cannot be properly isolated.

Furthermore, after such a disease as measles or scarlet fever has gone through a town it exhausts the supply of persons prone to these diseases; and apart altogether from any sanitary measures, some years may elapse before sufficient material has accumulated to furnish fuel for another outbreak. In addition to this, there are cyclical influences, the nature of which is imperfectly known, but which have important bearings on the prevalence of a given disease. So that neither, on the one hand, the comparative absence of a given infectious disease since notification came into force, nor, on the other hand, its increased prevalence, necessarily proves the utility or inutility of notification.

It should be remembered also that the materials available for drawing conclusions are very scanty, and that in many towns the period since notification began is too short to enable valid conclusions to be drawn.

In attempting comparisons of death-rates from a particular infectious disease between periods before and after compulsory notification was enforced, the following precautions must be particularly regarded :—

(1) Avoid average statements for groups of years. In treating of epidemic diseases no method is so likely to conceal the truth as this. In connection with small-pox statistics it has led to numerous errors. In other infectious diseases it is frequently quite practicable to show an increase or a decrease of mortality by adjusting the groups of years. The only proper method is to compare year by year, if practicable in a long series, and the data necessary for this can be best displayed by making a curve of the annual death-rate for the period under comparison.

(2) Remember that, as in scarlet fever, the mortality from a disease may decline to a much greater extent than its prevalence.

(3) Note that in view of the fact that the birth-rate in England is declining, and the age distribution of the population is consequently becoming modified, it is desirable in exact inquiries to state the amount of infectious disease at different age-groups for successive years in proportion to the number living at each age-group. This is especially important for the diseases occurring chiefly in infancy, as diarrhœa, the amount of which may be grievously misrepresented if it is stated in proportion to the population living at all ages, and not in proportion to the infantile population.

National Registration of Infectious Diseases. The possession by each medical officer of health of information as to the amount and nature of the infectious diseases prevalent in his own district does not exhaust the possibilities of utility of these returns. Their value would be greatly increased by collateral information as to the amount and nature of the infectious diseases prevalent in neighbouring districts and in the rest of the country, or even in other countries. By such an interchange of prompt and trustworthy information it would be practicable to forecast the possibilities of the introduction into a community of a given disease, and take suitable precautions. This defect in local notification was soon seen, and at the beginning of 1888 Dr. Tatham, then medical officer of health of Salford, made a private arrangement with the medical officers of health of thirty-two other notification-towns, by which he should receive from them weekly returns of the cases notified in each town. These were tabulated by him, and circulated confidentially amongst the contributing medical officers early in the succeeding week. The practicability and the utility of this voluntary inter-notification having been fully established, many of the local authorities of the towns concerned petitioned the Local Government Board to take the matter in hand as a "going concern"; and in 1889 the Board undertook the tabulation and distribution of the statistics of cases of sickness notified to the medical officers of health of those towns in which the notification of infectious diseases is compulsory. Only the co-operating towns receive the table summarizing the statistics of these notification-towns; and it is marked "not for publication." * We may reasonably hope, however, that this beginning will ere long end in a national registration of infectious diseases, and a similar tabulation and distribution of the national statistics. On two occasions departments of the Government have tabulated and circulated returns of sickness: first, metropolitan sickness of all kinds in 1857, and, secondly, infectious diseases in contributing notification-towns from 1889 onwards. These facts establish a valuable precedent, and furnish hope that a governmental department may soon be induced to take up in a much more complete and general form the collation of the general sickness statistics of the community, so far as they can be made available.

Suggestions as to Notification of Infectious Diseases. The notification enforced in the Infectious Disease (Notification) Act is "dual." The advantage of this is that the householder being associated in compulsion with the medical practitioner, the latter avoids any possible odium. The chief disadvantages are that (*a*) the dual method will, in the event of secrecy being desired, prevent a medical man being called in. This has not been found to operate largely in actual fact; and even if so, the same thing would happen if the onus of notification rested solely on the householder. (*b*) The fact that the householder is bound to notify "as soon as he becomes aware" that a patient is suffering from a notifiable disease presupposes some medical knowledge on his part, an assumption the advisability of which most medical men would doubt. Where a medical man has notified, notification by the householder has always been practically a dead letter; but what of cases for which no doctor is called in? It is usually impracticable to obtain in such cases a conviction for non-notification, because there is no provision in the law throwing the onus of proof of ignorance on the householder.

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* The annual report of the medical officer to the Local Government Board embodies a tabular statement of the number of notified cases and registered deaths from the notifiable infectious diseases in each of eighty-one urban sanitary districts quarter by quarter, and a weekly statement of the same facts for each of the sanitary districts of London (pp. 119–172, Report for 1895-96). The utility of this return would be greatly increased if it were published as a separate document at an earlier period than the entire report of the medical officer can be issued.

It is very desirable that the present machinery of the Infectious Disease (Notification) Act should be made more elastic and more comprehensive. In Germany and Scandinavian countries diseases are classified into two categories,* according as immediate or weekly notification is required. Such a grouping would enable a considerable extension of notifiable diseases in this country without commensurate increase of expense. Among the less urgent diseases for which a monthly or weekly notification would suffice would come tubercular diseases, especially phthisis. The time is ripe for greatly extended preventive measures against the spread of tuberculosis.

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* For particulars see paper by the author, *Jour. Royal Statist. Soc.*, vol. lix. part i.

CHAPTER VII.

MARRIAGES.

MARRIAGE statistics possess great interest for all who are concerned with the welfare of the people, affording as they do a valuable index of national prosperity, and incidentally in England throwing an interesting light on the progress of elementary education.

Estimation of Marriages. (1) The usual method is to state the proportion to the actual population, or the number per 1000 living. Although this method is fairly reliable in comparing the same town or community in successive years, it might lead to some inaccuracy if employed in comparing different communities in the same year, inasmuch as, owing to varying age and sex constitution and other circumstances, the number of marriageable persons living in different communities must vary considerably.

In the following table the highest and lowest marriage-rates in the chief European countries are given. The variations of the marriage-rate in each country may be studied in further detail by consulting Tables 44–61, pp. 115–122, in the *Registrar-General's Annual Report*, 1896.

MARRIAGE-RATE (PERSONS MARRIED) PER 1000 OF POPULATION SINCE 1864.

	Highest.		Lowest.
Hungary	20·8 in 1879	...	16·3 in 1889 (since 1876)
Austria	20·7 ,, 1869	...	15·1 ,, 1877 and 1890
Prussia	20·7 ,, 1872	...	14·8 ,, 1870 (year of war)
France	19·5 ,, 1872	...	12·1 ,, 1870 (year of war)
Switzerland	18·0 ,, 1875	...	13·7 ,, 1880–82 (since 1871)
Denmark	17·8 ,, 1865	...	13·6 ,, 1891
England and Wales	17·6 ,, 1873	...	14·2 ,, 1886
The Netherlands	17·1 ,, 1873	...	13·8 ,, 1888
Italy	16·8 ,, 1875	...	11·3 ,, 1866 (since 1866)
Norway	15·7 ,, 1875	...	12·2 ,, 1888 (since 1871)
Belgium	15·7 ,, 1866	...	13·4 ,, 1878 and 1886
Scotland	15·5 ,, 1873	...	12·6 ,, 1886
Sweden	14·6 ,, 1873	...	10·9 ,, 1868
Ireland	10·9 ,, 1865	...	7·8 ,, 1880

(2) The more accurate method of calculating the marriage-rate for comparative purposes is to base it on the number of bachelors, spinsters, widowers, widows, and divorced persons living at marriageable ages. The number of these can be obtained for the census year from the census returns for each registration and sanitary district in England (*Census Report*, 1891, vol. iii.), and it may be assumed that the same method of estimation for increase of this portion of the population can be adopted as that described (p. 6) for the whole population.

The question arises whether the relative place of the above countries would be altered were this more accurate method of calculating the marriage-rate adopted. Dr. J. Bertillon* has calculated for many European countries the number of persons married annually per 1000 marriageable persons, *i.e.*, persons over fifteen years of age who are celibates, divorced persons, or widowed. The highest on the list is Hungary (72·6), next come in order Saxony (60·8), Prussia (51·0), England and Wales (50·2), Denmark (47·9), Italy (47·5), France (45·4), Belgium (40·0), Scotland (39·6), Sweden (36·9), and Ireland (23·1 per 1000 marriageable persons over fifteen years of age).

The above rates are calculated on the returns for each country for the years 1878–82. The high marriage-rate in Hungary is ascribed by Dr. Bertillon to the frequency of remarriage of widowers, and indirectly to the high mortality in that country. Judging by the marriage-rate per 1000 of total population, Hungary is surpassed by the purely Slavonic races of Croatia-Slavonia, Servia, and Russia.

Calculated by either of the above methods, Hungary shows the highest marriage-rate among the countries for whom exact figures are given above and on page 57; Prussia is high in both, while the marriage-rate of England and Wales is, from a comparative standpoint, much higher, and that of France lower, when calculated by the more accurate method.

Condition as to Marriage of the English Population. Between 1881 and 1891 the average annual marriage-rate was very considerably lower than that of the immediately preceding decennium. Notwithstanding this the proportion of married and widowed persons in the population did not show any marked decline, as may be seen from the following table:—

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* *Éléments de Démographie*, 1896, p. 33.

PROPORTION OF SINGLE, MARRIED, AND WIDOWED PERSONS IN THE POPULATION PER 1000 LIVING, 1881 AND 1891.

Year.	Males.			Females.		
	Bachelors.	Husbands.	Widowers.	Spinsters.	Wives.	Widows.
1881	620	346	34	592	333	75
1891	620	345	35	596	329	75

This seeming paradox is explained by the fact that, although a decline of the marriage-rate diminishes the proportion of married men and women in the population, it also diminishes the proportion of the unmarried by causing a lowered birth-rate. The varying degree of migration among married and unmarried, and the varying degree of lowering of the death-rate at different age-groups, have co-operated in producing the above result.

Of the male population of all ages at the 1891 census 35 per cent. were married men, while of the female population only 33 per cent. were wives; if widowed persons are also taken into account, the proportions become 38 per cent. for the men and 40 per cent. for the women.

Higher Marriage-Rate in Towns. The marriage-rate is always higher in large towns than in rural districts. This is chiefly explained by the fact that a large number of young country-people resort to populous districts, where, owing to the presence of large trades and manufactures, higher wages can be secured, and there they marry. In towns there is nearly always an excess of persons between twenty and forty years of age. Many also resort to towns merely to be married, subsequently returning to rural districts.

Influence of National Prosperity on Marriage-Rate. Dr. Farr has described the marriage-rate as the barometer of prosperity (present in part, but future anticipated prosperity in still greater part), just as the funds are the barometer of credit. So we find that the marriages of England increase as "the result of peace after war, abundance after dearth, high wages after want of employment, speculation after languid enterprise, confidence after distrust, national triumphs after national disasters."

The same conclusion is borne out by the fact, frequently alluded to by the Registrar-General in his reports, that the marriage-rate varies in the same direction as the value of British exports, the average price of wheat, and the amount per head of population cleared out at the Bankers' Clearing House. The coincidence, it should be pointed out, is one in direction, but not in degree. (See Table A. p. vi. *Registrar-General's Annual Report*, 1896.) The subject is ably discussed in a paper by Dr. W. Ogle (*Jour. Royal Statist. Soc.*, vol. liii. part ii. 1890).

Decline of Marriage-Rate. Notwithstanding the increasing wealth of the country the marriage-rate has declined, with intermittent smaller rises, from a maximum of 17·6 in 1873 to 15·0 in 1895. It is probable that the steadily increasing standard of comfort among all classes, rendering men and women unwilling to undertake the responsibilities of family life without an assured income, has been chiefly instrumental in bringing this about. A similar decline has occurred in other countries. In France, Prussia, and the German Empire it set in a year earlier than in England. In the former countries the diminution appears greater, owing to the abnormally high marriage-rate in 1872, at the conclusion of the Franco-Prussian war.

Marriage Calendar. The Registrar-General's statistics show that most marriages occur in December, October, April, and June. The greater number of marriages in December, April, and June are accounted for by the festive periods of Christmas, Easter, and Whitsuntide coinciding with these months; while October is the period after the harvest, when the agricultural labourer has comparative leisure as well as money in his pocket. The month of May, owing to a widespread superstition that it is an unlucky month for marriages, is lowest on the list.* The favourite days in the week for marriages are Saturday, Monday, and Sunday.

Marriages and Remarriages. In 1896, of the total marriages of men 89·7 per cent. were of bachelors and 10·3 per cent.

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* Mr. S. A. Matthew, of Cambridge, writing to the author on this point in 1895, states: "I think that this is doubtless a survival of an old Pagan superstition. Brand twice refers to it in his *Popular Antiquities*, ed. 1849, i. 224, ii. 168. Ovid, in the *Fasti*, says: 'Mensœ malum Maio nubere vulgus ait.' And in this month were held the Festival of Bona Dea and the Feasts of the Dead."

of widowers. Of the total marriages of women 92·7 per cent. were of spinsters and 7·3 per cent. of widows. The proportion of widowed persons who remarry has steadily declined. Thus

	In 1000 Marriages	
	Widowers.	Widows.
1871–75	138	100
1891–95	113	79
1896	103	73

Ages at Marriage. The English statistics under this head are imperfect, owing to the phrases "full age," "minor," "under age" being frequently inserted in the register. There is, however, a steady improvement in this respect; for while in 1851 in 63 per cent. of the total marriages the precise age of one or other of the contracting parties was not stated, in 1861 the proportion had fallen to 37, in 1871 to 29, in 1885 to 8·5, and in 1895 to 2·4 per cent.

Of the total marriages in 1895 in which the age of the contracting parties was stated, the mean age of the women married was 26·2 years, and of the men 28·4 years. Taking marriages and remarriages separately, the mean age of widowers married was 44·3 years; of widows, 40·5 years; of bachelors, 26·6 years; and of spinsters, 25·0 years. Postponement of marriage of course limits the childbearing period; and a portion of the lowering of birth-rate which has occurred of late years may be ascribed to this cause.

The mean age at marriage has been gradually rising since 1873. In that year there was great prosperity, and the marriage-rate was at its maximum, the mean age of bachelors at marriage being 25·6 and of spinsters 24·2 years, the lowest recorded. Since then the mean age at marriage has gradually risen, the figures for 1895 (see Table B. p. viii. *Registrar-General's Annual Report*, 1895) being the highest yet recorded. When the marriages are few in number they are also delayed to a somewhat later period of life.

Mr. C. Ansell in his *Statistics of Families in the Upper and Professional Classes* (page 44) found that the mean age at marriage of bachelors of these classes during the period 1840 to 1871 was 29·95 years.

Further statistics as to average ages at marriage of bachelors and spinsters in occupational groups will be found on page viii. *Registrar-General's Forty-ninth Report*, 1886. Comparing the two extreme instances given in this report we have the following result:—

	Average Age at Marriage of	
	Bachelors.	Spinsters.
Miners	24·06	22·46
Professional and Independent Class	31·22	26·40

Thus with higher social status not only the average age at marriage, but also the difference between the ages of husband and wife increases.

At the census of 1891 the number out of 1000 males and females respectively at each age-group who were married was as follows:—

CONDITION AS TO MARRIAGE OF 1000 MALES AND OF 1000 FEMALES AT SUCCESSIVE AGE-PERIODS, 1891 (*Census Report*, vol. iv. p. 34).

Ages.	MALES.			FEMALES.		
	Single.	Married.	Widowed.	Single.	Married.	Widowed.
All ages	620	345	35	596	329	75
Under 15	1000	—	—	1000	—	—
15—	996	4	—	980	20	—
20—	806	192	2	701	296	3
25—	343	645	12	326	653	21
35—	147	819	34	164	761	75
45—	100	827	73	124	706	170
55—	84	771	145	110	573	317
65 & upwards	73	590	337	107	319	574

Marriage of Minors. The proportion of marriages under age has shown a steady decline, as will be seen from the following figures (*Registrar-General's Fifty-ninth Report*, 1896):—

	Marriages under age in 1000 Marriages.	
	Men.	Women.
1871–75	82	223
1876–80	78	217
1881–85	73	215
1886–90	63	200
1891–95	56	183
1896	53	174

Signatures in Marriage Register. These throw an interesting side-light on the state of elementary education in England, as indicated by the inability to sign the marriage-register.

In 1841, out of every 100 men married 33, and out of every 100 women married 49, were unable to sign the marriage-register. The proportion has steadily declined, until, in 1895, only 4·0 per cent. of the men and 4·8 per cent. of the women signed the marriage-register with marks, instead of with their names.

In the country as a whole, the number of men unable to write is considerably less than that of women, though the difference between the two sexes is rapidly diminishing. Taking the counties separately there is great discrepancy, the general rule being that in agricultural counties (particularly the southern) the male, and in mining and industrial counties (particularly the northern) the female, is the worst educated sex.

In the northern part of the country the amount of illiteracy is much greater for each sex than in the southern part.

CHAPTER VIII.

FECUNDITY OF MARRIAGE.

MARRIAGE being the great institution by which the population is chiefly regulated, it becomes necessary to consider the conditions regulating the fertility of marriage. The two most important of these are the duration of married life, and the age at which marriage is contracted by women, which are to a large extent mutually inter-dependent.

From the English census 1891, the number of wives under forty-five years of age can be ascertained. Comparing these with the number of legitimate births in the three years 1890–92, the average annual fecundity of wives of reproductive ages is represented by 264 live births to 1000 wives. Similar calculations made from the returns of 1881 and 1871 respectively give annual fecundities of 286 and 292 per 1000 wives. A gradual reduction of fecundity is thus shown. This reduction of fertility is partially ascribable to the lowering of the marriage-rate, which is necessarily associated with a reduction of the proportion of newly-married women among the wives under forty-five, and partially also to the raising of the mean age at marriage.

Dr. J. Bertillon[*] prefers the age-group 15–50 for calculating the legitimate birth-rate, and some of his results are here reproduced:—

	Years of Observation.	Legitimate Birth-rate per annum to every 1000 wives aged 15–50 years.		Illegitimate Birth-rate per annum to every 1000 unmarried women aged 15–50 years.	
		Including still-born.	Excluding still-born.	Including still-born.	Excluding still-born.
France .	1878–82	173	166	17	16
Belgium .	do.	275	263	20	19
Italy .	do.	249	242	25	24
Germany .	do.	278	265	29	28
Austria .	do.	250	244	46	44
Sweden .	do.	245	239	22	21
Norway .	do.	283	274	20	19
Denmark .	do.	248	240	27	26

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[*] *Op. cit.*, p. 43.

The following figures are taken from the 1890 Census Report of the United States (part i. on "Vital and Social Statistics," p. 481):—

	Birth-rate per 1000 of					
	All Females between 15 and 50 years of Age.			Married Females between 15 and 45 years of Age.		
	Total.	White.	Coloured.	Total.	White.	Coloured.
Registration Area. .	85	86	78	184	184	175
Cities . .	88	89	77	192	193	172
States . .	81	81	80	176	176	184

Thus the birth-rate of the coloured was less than that of the white, and the birth-rate of the white population was greatest in the cities.

The figures in the preceding table have only an approximate value, being based on somewhat incomplete data. The same remark applies to the following table from a paper by Dr. Wilbur in the Annual Report on the Vital Statistics of Michigan for 1894.

THE FECUNDITY OF MARRIAGE OF NATIVE-BORN AND FOREIGN-BORN WOMEN IN MICHIGAN, 1870–94, IN FIVE-YEAR PERIODS, APPROXIMATE CORRECTIONS HAVING BEEN MADE FOR IMPERFECT RETURNS.

Five-year Periods.	Children born per 1000 women between 15 and 45 years of Age.		Children born per marriage, with mother.	
	Native.	Foreign.	Native.	Foreign.
1870–74	124	231	—	—
1875–79	127	235	3·6	6·5
1880–84	122	221	3·3	6·5
1885–89	117	227	3·0	4·9
1890–94	111	232	3·0	5·1

The *age at marriage* is the chief factor controlling the proportion of children to a marriage, the age of the wife being the most important element, because of the fact that child-bearing is limited practically between the sixteenth and forty-fifth years of life. The fathers and mothers of nearly half the children born are, according to Dr. Farr, under thirty years of age.

What amount of Reduction in the Marriage-Rate would be required to produce under present conditions a stationary population? Dr. Ogle has discussed this subject in detail in the *Jour. Royal Statist. Soc.*, vol. liii. part ii.

His calculations show that "in the very improbable event of all women retarding their marriages for five years, we should have a birth-rate of 23·3 per 1000," which, on the basis of the death-rate of 17·8 in 1888, would still leave the population growing at the rate of between 5 and 6 per 1000 annually. It is evident that in view of the fact that in the last 23 years the mean age at marriage of spinsters has only increased by 0·8 years, we may "dismiss altogether the notion that any adequate check to the increase of population is hereafter to be found in retardation of marriage."

Similarly, if without any alteration in the age at marriage we attempt to secure a stationary population by simple decrease of the marriage-rate, we have, taking the figures of 1888, to inquire what marriage-rate corresponds to the legitimate birth-rate of 16·4 in that year. The average number of children to a marriage being about 4·2, the marriage-rate would have to be $\frac{16{\cdot}4}{4{\cdot}2} = 3{\cdot}9$, or, expressed according to the English method (there being two parties to a marriage), 7·8 per 1000, *i.e.*, 45 per cent. below the point it has ever yet touched.

How if both methods are combined? It can easily be calculated that with an average of 3·1 children to a marriage, resulting from an average retardation of female marriage for 5 years, a marriage-rate of 10·6 per 1000 would give a legitimate birth-rate of 16·4, which with 1·4 for the illegitimate birth-rate would give a total birth-rate of 17·8, which is also the death-rate of 1888. Or as Dr. Ogle sums up: "If one-quarter of the women who now marry were to remain permanently celibate, and the remaining three-quarters were to retard their marriages for five years, the birth-rate would be reduced to the level of the present death-rate."

Age in Relation to Fecundity. M. Körösi (Budapesth)* has drawn up *tables of natality* (*Philos. Trans.*, 1893) analogous to a life-table, in which a separate statement of the probabilities of a birth is given for each age of life. If we assume the duration of fecundity in the male to be about fifty years, and that of the female about forty years, the question of fecundity can only be solved by a division into at least 2000 questions, since each year of age of one parent must be combined with each year of age of the other. Such *tables of natality*, giving the probability of a birth for each combination of ages of fecundity, have been possible in Budapest since 1889, as the birth returns state *inter alia* the ages of parents, previous births in same family, etc. The census returns for 1891 gave the number of couples living among the same combinations of ages. From four years' observations, embracing 46,931 births, the ratio of annual births to 1000 marriages is found to be 163. But many of the total marriages having passed the period of prolificity, a separate statement must be given for each year of life. Körösi gives his results both mono-sexually and bi-sexually. Stating them *mono-sexually* they show that the fecundity of the *female* in Budapest reaches its maximum between the 18th and 19th year, descending then in a regular line to the age of 45–50, when it ceases. Every hundred marriages of girls under eighteen years of age only produce within a year 36–38 infants. From 18–20 years, fecundity reaches its maximum of 40 per cent., *i.e.*, 40 children within a year. At 25 years, it is 32 per cent; at 30 years, it is 24 per cent; at 35 years, 17 per cent; at 40 years, scarcely 7 per cent; at 50 years, 0·1 per cent.

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* A Study of the Laws of Increase of Population, *Public Health*, vol. viii. p. 100.

Men attain the maximum of their fecundity at 25–26 years, when it is 35 per cent; at 35 years it has fallen to 23 per cent.; at 45, to 9·5 per cent.; at 55, to 2·2 per cent.; and at 65, to 0·5 per cent. The figures relate to effective, and not to physiological fecundity. Prudential considerations frequently come into operation in later married life, as clearly shown by the following figures:—

FECUNDITY OF MARRIAGE AT VARIOUS AGE-GROUPS.

Age.	For Women newly-married.	For all Women.
30–34 years.	32·9 %	20·6 %
35–39 „	32·7 %	14·7 %
40–44 „	21·4 %	5·9 %

Stating the results *bi-sexually*, *i.e.*, according to the change of age in both parents, the following results are obtained. For 100 females of the following ages, the probability of a birth occurring in a year varies with the age of the man as follows:—

Age of Father.	Age of Mother.		
	25 years.	30 years.	35 years.
25–29 years.	35·6 %	25·0 %	21·2 %
30–34 ,,	31·2 %	23·6 %	19·9 %
35–39 ,,	27·5 %	21·8 %	19·4 %
40–44 ,,	—	16·7 %	14·0 %
45–49 ,,	—	14·4 %	10·9 %
50–54 ,,	—	—	10·9 %

On the other hand, the fecundity of the fathers varies as follows with the age of the mothers:—

Age of Mother.	Age of Father.			
	25 years.	35 years.	45 years.	55 years.
Under 20 years.	49·1 %	—	—	—
20–24 ,,	43·0 %	31·3 %	16·0 %	—
25–29 ,,	30·8 %	27·3 %	18·5 %	—
30–34 ,,	33·5 %	23·7 %	14·4 %	8·1 %
35–39 ,,	—	18·9 %	11·8 %	6·7 %
40–44 ,,	—	6·6 %	6·1 %	3·0 %

M. Körösi anticipates that these probabilities of birth may in time be practically utilised in the same way as the probabilities of mortality tables. The latter are the basis of life assurance, the former may furnish the basis of a new branch of assurance.

The same tables answer the question as to the appropriate age of the female to secure the greatest fecundity. Thus a man aged 25 years ought, from this standpoint, to choose a wife aged 19 years; a man aged 35 a wife aged 21 years; at 40 years a wife of 24; at 45 a wife of 29 years old.

In a contribution to the Royal Society on M. Körösi's tables, Mr. Francis Galton has made an ingenious attempt to reduce to a single formula the probability of births for numerous combinations of ages, and made further combinations of ages of the same fecundity, establishing between them similar connections to those seen in geographical maps for places of the same temperature and altitude. These lines, analogous to isotherms and isobars, are described as *isogènes*.

Duration of Married Life. In stating numerically the fecundity of marriage, the question arises as to what marriages shall be compared with the births of a given year. If we could follow the families and count all the children resulting from a given marriage to the end, the fecundity of the marriage would be accurately represented. If the annual marriages in a given community did not increase or decrease in number through a series of years, the division of the annual births by the annual marriages of the same years would express the fecundity; but when the marriages are rapidly increasing, an approximation to the fecundity can only be obtained by dividing the births by the marriages of some earlier year. The year to be selected is determined by the interval between the mean age at marriage and the mean age of mothers when their children are born; there are no data as to this interval in England. In Sweden it is 5·9 years. According to the New Zealand Year-book, 1894, it was in that country only 3·14 years in 1881, 3·33 years in 1886, and 3·62 years in 1891.

The following table from the *Registrar-General's Fortieth Annual Report* gives the comparative fecundity of various European States. During the three years 1876–79 the average number of births to a marriage in England was 4·57.

COMPARATIVE FECUNDITY IN DIFFERENT EUROPEAN STATES.

Years.	European States.	Births to a Marriage.
1876	Italy . . .	5·15
,,	Prussia . . .	4·92
,,	Sweden . . .	4·84
,,	Netherlands . .	4·83
,,	England . .	4·63
,,	Belgium . .	4·48
1870	Spain . . .	4·47
1876	Denmark . .	4·24
,,	Austria . . .	3·73
,,	France . . .	3·42

Assuming that the interval between the mean age of marriage and the mean age of mothers in England is six years, as in Sweden, then the legitimate births in 1874 divided by the average number of marriages in the three years 1867–9 will give the average number of births to a marriage, which was 4·57. In 1864 it was 4·30, but the apparent increase is probably owing to improved registration of births.

The corresponding figures for Michigan are given on p. 65.

The following figures are quoted by Dr. Wilbur* from the *Victorian Year Book*, 1894, p. 300. It is probable that the results have been obtained by various methods. They can therefore only be regarded as possessing an approximate value.

CHILDREN TO A MARRIAGE IN VARIOUS COUNTRIES.

Country.	Children to each marriage.	Country.	Children to each marriage.
Russia in Europe (1888)	5·7	Italy	4·6
Ireland	5·5	Scotland	4·4
New Zealand	5·2	Holland	4·3
Finland (1887)	5·0	Victoria	4·2
Russian Poland (1888)	4·9	Belgium	4·2
Western Australia	4·8	England	4·2
Tasmania	4·7	Sweden	4·0
New South Wales	4·7	Denmark	3·6
South Australia	4·7	Japan (1888-91)	3·5
Queensland	4·6	France	3·0

In New South Wales the age at marriage, together with the number of children she has borne, is registered in connection with the record of the death of each female. In the year 1893, the mean number of children borne by women married at 15–19 years of age inclusive is 6·76. From 20–24 inclusive it is 5·32, a loss of 1·44 children per marriage attending an advance of five years in age at marriage.

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* *Op. cit.*, p. 119.

CHAPTER IX.

BIRTHS.

THE consideration in the last chapter of marriages and their average fecundity naturally opens the way to a discussion of birth statistics. Such statistics are of value in giving information as to the rate of natural increase of the population, and the age and sex-distribution of the population, in addition to their great social interest, especially when the statistics of illegitimacy are included.

Estimation of Birth-rate. The birth-rate may be estimated by the following plans, of which the third is the most accurate, though not so easily available for ordinary purposes. (1) The birth-rate is reckoned as a rate per 1000 of the population living at all ages, in the middle of the year. This may be described as a *crude birth-rate.* It is fairly satisfactory when used for the same community in a series of years, or in comparing the birth-rates of communities whose populations are known to be nearly, if not quite, identical in their age and sex-composition. If, however, the number of women living at child-bearing years differs in two populations, the birth-rate per 1000 of the total population would vary from this cause, apart altogether from varying fecundity of the two populations.

We may (2) calculate the proportion which the births registered bear to the women living at child-bearing years—*i.e.* roughly between about 15 and 45 years of age. These are shown by the census returns for each urban and rural sanitary district; and as the age and sex-composition, except in abnormal cases, does not vary greatly in an intercensal period, the same proportion of women aged 15–45 to the total population may be regarded as holding good throughout the intervening period between any two census enumerations.

(3) The second method would be sufficiently accurate in comparing two towns like Bradford and Leeds, in which the social and industrial conditions are presumably identical. If, however, an industrial parish like Whitechapel were to be compared with a fashionable district like South Kensington by either the first or second method given above, the results would be misleading.

And, speaking generally, the only completely accurate method of stating the birth-rate is to subdivide the births into legitimate and illegitimate, stating the former per 1000 of married women of child-bearing years, and the latter per 1000 of unmarried women of child-bearing years. The relative accuracy of the two former methods and of the last method is shown in the following table:—

LEGITIMATE BIRTH-RATES IN KENSINGTON AND WHITECHAPEL. 1891.

	Kensington.	Whitechapel.	Percentage excess of birth-rate in Whitechapel over that in Kensington.
A. Birth-rate per 1000 inhabitants	21·8	39·9	83 %
B. Birth-rate per 1000 women aged 15-45 years . .	61·6	172·1	177 %
C. Birth-rate per 1000 married women aged 15–45 years .	215·4	328·3	53 %

The social condition of Kensington implies a large proportion of female unmarried servants, who contribute but little to the birth-rate. Among married women of the child-bearing age the true birth-rate is 53 per cent. higher in Whitechapel than in Kensington (C). The statement of the birth-rate by the ordinary method (A) exaggerates the true difference to the extent of 30 per cent., while its statement by the second method (B) exaggerates it to the extent of 124 per cent.

A tabulation of the comparative illegitimate birth-rates for the two above districts will complete our illustration of the methods of statement of birth-rate.

ILLEGITIMATE BIRTH-RATES IN KENSINGTON AND WHITECHAPEL, 1891.

	Kensington.	Whitechapel.	Percentage excess of illegitimate birth-rate of Whitechapel over that of Kensington.
A. Birth-rate per 1000 inhabitants	1·19	1·26	6 %
B. Birth-rate per 1000 women aged 15-45 years . .	3·35	5·44	62 %
C. Birth-rate per 1000 unmarried women aged 15-45 years .	4·68	11·43	136 %

Thus a statement of the illegitimate birth-rate in terms of the entire population gives the completely erroneous impression that illegitimacy is nearly equal in amount in Kensington and Whitechapel. A statement in proportion to the total number of women aged 15-45 only shows an excess of 62 per cent. in the latter; while a statement in proportion to the number of unmarried women at child-bearing ages shows that it is nearly two and a half times as high in Whitechapel as in Kensington (excess of 136 per cent.).

Defects in Registration of Births. Prior to the operation of the Civil Registration Act of 1837 there were no trustworthy birth statistics. In the earlier years of the operation of the Act registration of births was undoubtedly defective, Dr. Farr estimating the deficiency during the 39½ years ending with 1876 at 5 per cent. The registration of births was first made compulsory by the Births and Deaths Registration Act of 1874; and it is probable that at the present time the failure of registration is very small, and chiefly confined to illegitimate births. There are two grave defects in the Birth Registers of the United Kingdom. The ages of the mothers at the birth of each of their children are not stated, nor is the order of their birth recorded, so that the number of children borne by women at different ages, and the total number in the course of their lives, cannot be ascertained in this country.

National and International Birth-rates. The total English birth-rate, legitimate and illegitimate, averaged 32·6 per 1000 of population in 1841–50. It reached its maximum (36·3) in

1876, and since then has steadily declined to a minimum of 29·6 in 1894. In 1895 it rose to 30·4, and in 1896 it was 29·7.

The relationship between the crude birth-rate and the true birth-rate may be gathered from the following data for the two census years 1881 and 1891 :—

ENGLAND AND WALES.

	1881		1891.	
	Legitimate.	Illegitimate.	Legitimate.	Illegitimate.
Birth-rate per 1000 persons at all ages	32·2	1·7	30·1	1·3
Birth-rate per 1000 married or unmarried women aged 15–45 years . .	285·6	14·1	268·0	10·6

The teaching of this table may be further elucidated by stating the percentage decline of each rate for 1891 when compared with corresponding rates for 1881.

DECLINE PER CENT. OF BIRTH-RATE OF ENGLAND AND WALES BETWEEN 1881 AND 1891.

	Legitimate.	Illegitimate.
(*a*) Of crude birth-rate	6·5 %	23·5 %
(*b*) Of accurately determined birth-rate . .	6·2 %	24·8 %

The conclusions derived from the accurately determined birth-rate confirm in the main those derived from the crude birth-rate ; the differences being that the legitimate birth-rate has declined slightly less and the illegitimate birth-rate considerably more than the crude rates would indicate.

On p. 64 will be found accurately determined birth-rates for some other European countries.

The English birth-rate varies considerably in different **counties,** the lowest rates occurring in the agricultural, and the highest in mining and industrial districts. Thus in 1895 the lowest birth-rates were in Sussex (24·3), Surrey (25·0), Westmoreland (25·4) ; the highest in Monmouthshire (35·0), Staffordshire (35·6), and Durham (35·8).

The higher birth-rate in **urban populations,** which are to a great extent included in mining and industrial districts, is owing in part to the higher marriage-rate, and in part to the earlier marriage of women, and the greater mortality among infants, which, by shortening the period of suckling, diminishes the intervals of child-bearing. But the chief reason is doubtless the fact that in urban populations there is a greater proportion of women at child-bearing ages.

In the thirty-three great towns the birth-rate in 1897 averaged 30·7 per 1000 inhabitants, varying from 22·5 in Halifax, 23·4 in Huddersfield, and 24·6 in Bradford, to 35·1 in Salford, 35·3 in Liverpool, and 35·8 in Gateshead. The differences between the crude birth-rates of these towns represent in part real differences of fecundity; in part, differences of a social and industrial character, causing differences in the proportion of the total population who are married women of child-bearing age. The proportional share of these factors can only be shown by a system of correction, of which I have already given two examples (pp. 72 and 73).

Social Position has a considerable influence on the birth-rate, though there are very few accurate data on this point. The fallacy involved in the fact that people's social position tends to improve as their ages advance should be remembered. We have already seen (p. 61) that persons of the higher classes marry at a later age than others. There are, as we have also seen, serious fallacies involved in comparing the crude birth-rate of two populations. The following further instance may be given: The late Sir E. Chadwick compared the metropolitan births, which at the time of his remarks were 1 in 37 of the population, with those of Herefordshire, which were 1 in 44; but Mr. Neison showed that this difference was largely explained by the fact that while the population aged twenty to forty was 36·33 per cent. of the total population in London, it was only 28·39 per cent. of the total population in Herefordshire. Dr. J. Bertillon, at the meeting of the International Statistical Institute at St. Petersburg, September, 1897, gave the following statistics as to the births per 1000 women aged fifteen to fifty per annum in different quarters of the under-noted cities:—

Classification.	Paris.	Berlin.	Vienna.	London.
Very poor quarters . .	108	157	200	147
Poor quarters . . .	95	129	164	140
Comfortable quarters . .	72	114	155	107
Very comfortable quarters .	65	96	153	107
Rich quarters . . .	53	63	107	87
Very rich quarters . .	34	47	71	63
Average . . .	80	102	153	109

Probably the birth-rate is really higher among the poor than the rich, but the preceding figures cannot be entirely trusted—at least, so far as London is concerned. They require to be checked by calculation of the legitimate birth-rate per 1000 married women at child-bearing age in each district (see p. 72).

The influence of **National Prosperity** on the birth-rate is in the same direction as its influence on the marriage-rate (pp. 59 and 60).

The birth-rate in England varies slightly according to **season.** In the first quarter of 1893 the English birth-rate was 31·5, in the second, 31·7, in the third, 30·6, and in the fourth, 29·2 per 1000 of the population. The data for ascertaining the four-weekly birth-rate in London are given on p. liii. of the *Annual Summary of Births, Deaths, etc.*, 1897.

In the *Statistisches Jahrbuch* for Berlin, 1895, the following table is given:—

The average Daily Number of Births for each Calendar Month stated in Proportion to the average Daily Number for the Whole Year=100.

	Live-Born.	Still-Born.	Total.
January . .	105·4	99·5	104·6
February . .	104·7	112·9	105·9
March . . .	104·5	110·3	105·4
April . . .	98·1	110·5	99·9
May . . .	100·5	107·2	101·5
June . . .	101·6	96·4	100·8
July . . .	103·1	89·2	101·1
August . . .	101·8	97·9	101·3
September . .	101·4	101·0	101·3
October . . .	95·5	88·1	94·4
November . .	90·1	89·7	90·0
December . .	93·3	87·3	93·8
	100·0	100·0	100·0

The following details from the *Bericht des Medicinalrathes über die Medicinische Statistik des Hamburgischen Staates*, 1896, may be added, especially as no such data as to still-births are possible under the present system of registration in the English Registrar-General's reports:—

CITY OF HAMBURG—MONTHLY BIRTHS.

	Percentage of Total Annual Births occurring in each Month.		Percentage occurring in each Month of 1896, of	
	Mean of 1881–90.	1896.	Live Births.	Still Births.
January	8·2	8·2	8·3	7·9
February	8·6	8·6	8·6	9·1
March	8·7	8·7	8·6	9·4
April	8·3	8·2	8·0	9·6
May	8·3	8·1	8·1	7·4
June	8·1	8·2	8·1	8·7
July	8·2	8·2	8·4	7·0
August	8·3	8·2	8·3	7·4
September	8·5	8·6	8·8	7·6
October	8·3	8·2	8·2	8·5
November	8·2	8·5	8·5	7·7
December	8·3	8·3	8·1	9·7
	100·0	100·0	100·0	100·0

The Berlin and Hamburg returns are interesting, as showing that, with one exception (December in Hamburg), the highest proportion of still-births in both cities occurs in the months of February, March, and April. The three months in which the highest proportion of live-births occurs are January, February, and March in Berlin, and September, February, and March in Hamburg.

The influence of **Nationality** is shown in Fig. 4. The comparative birth-rates for twelve European countries, as well as the constituent parts of the United Kingdom, are given in the English Registrar-General's reports (1896, pp. cxv.-cxxxii.), the longest annual series being that for Sweden, which dates back to 1851. There has been a general decline in the birth-rate, though this is much more marked in some countries than in others. This decline has almost ceased in the last two years.

Causes of Decline in Birth-Rate. The explanation of the steadily declining birth-rate must be sought in some cause or causes which are in operation throughout the civilized world, as the phenomenon is a general one. The greater extent of the decline in the birth-rate in certain countries will help in determining the chief operating causes. The two in which the decline is apparently the greatest are France and Massachusetts. Of the

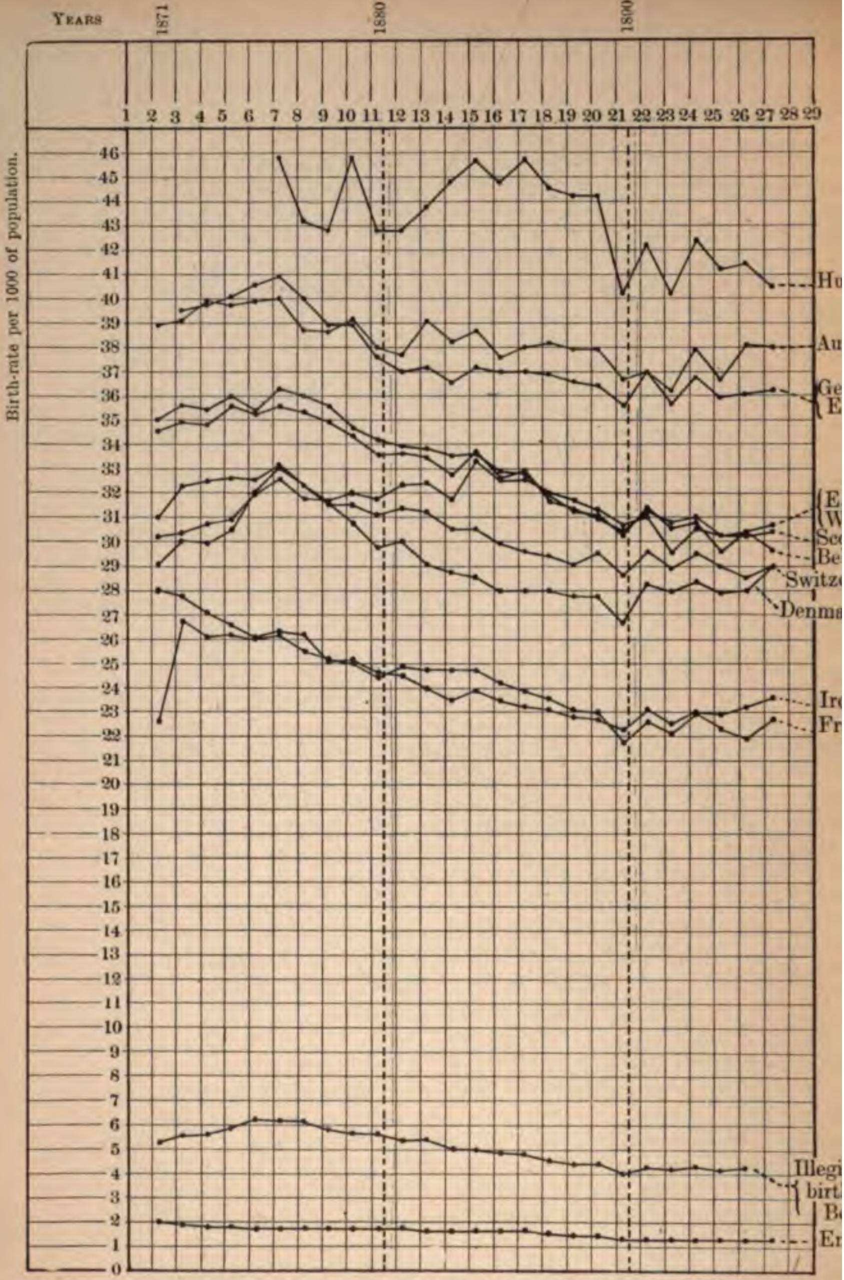

FIG. 4.—Birth-rates, 1871–95, in different European countries.

latter Mr. Dike, quoted by Dr. Wilbur,* says: "The declining fruitfulness of the family, especially among people of the so-called native stock, has become a matter of serious concern. In Massachusetts, the mother of foreign birth has on an average 50 per cent. more children than the mother born in this country. France is the only country in Europe whose birth-rate is as low as that of Massachusetts, and France is alarmed at her condition. Massachusetts is indifferent, for she can recruit her population from Ireland and Canada."

It will have been seen from previous remarks (p. 66) that

(*a*) Postponement of marriage to more mature years, and (*b*) a larger proportion of celibacy, only account for a share of the decreased birth-rate.

(*c*) The greater ease with which divorce is obtained in non-Roman Catholic countries has a certain amount of influence, especially as many of the divorces occur at child-bearing ages, and the divorced often do not re-marry. The mean duration of married life was calculated by Farr in 1871 to be 27 years. Dr. Wilbur states that the mean duration of marriages interrupted by divorce in Michigan is less than 10 years.

(*d*) There is no reasonable ground for the view that a diminished power of either sex to produce children has been produced by alcohol, syphilis, tobacco, or other causes.

(*e*) It is quite clear that the main cause of the diminution in the birth-rate is "the deliberate and voluntary avoidance of child-bearing on the part of a steadily increasing number of married people, who not only prefer to have but few children, but who know how to obtain their wish."† That this is the chief reason is shown by the extremely high birth-rate among the French population in Canada, and the abnormally low birth-rate in France. The difference is inexplicable on the score of climate, or indeed of any other known cause, except that the former who are orthodox Roman Catholics are prohibited by their religious beliefs from practising the artificial means of preventing large families which find favour in France.

Still-births are not registered in England; but under the Registration Act no still-born child can be buried without a certificate from a registered practitioner in attendance, or from one who had examined the body, or in his absence a declaration from a midwife or some other person qualified to give the information to the effect that the child was still-born. The proportion of still-births to total births in this country is supposed to be about 4 per cent.; but this is uncertain. In France and Belgium the children dying either before or after birth, if they die before registration, are recorded as still-born. This fact should be remembered in estimating the true death-rate and birth-rate of France. Thus the corrected death-rate of France in 1875 becomes 23·4, instead of 23·1, per 1000 of population (*Registrar-General's Thirty-eighth Annual Report*). In Italy, Germany, and in the four Scandinavian countries, the term "still-born" is used in the medico-legal sense.* The proper plan would be to register all still-births in a separate category, distinct from both births and deaths. The males outnumber females in still-births, probably owing to greater difficulty in child-birth. Thus, in the ten years 1865–1875, they were in France, 144; Italy, 140; Belgium, 135; Sweden, 133; and in Prussia 129 to every 100 female still-births.

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* *Op. cit.*, p. 125.

† Paper by Dr. J. S. Billings, *Forum*, Dec., 1849.

In Berlin in 1895 the proportion of males to females among the still-born was 137 to 100, among the live-born 104 to 100. In Hamburg in 1896 the proportion of males to females among the still-born was 125 to 100, among the live-born 107 to 100. (See also p. 24.)

The proportion of still-born is greater among male illegitimate than among male legitimate children. This is clearly shown by the following figures† :—

Country.	Period of Observation.	Of every 1000 births, including still-born, the number of still-born, or declared as such, was as follows among—	
		Legitimate.	Illegitimate.
	(1) *Countries in which inquiry as to paternity is forbidden.*		
France	1878–82	42	78
Belgium	do.	43	58
	(2) *Countries in which inquiry as to paternity is allowed.*		
Prussia	1878–82	39	54
Austria	do.	24	38
Hungary	do.	14	30
Sweden	do.	28	37
Norway	do.	32	50

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* *i.e.*, a viable infant (having had over six months of intra-uterine life, or being twenty-five centimetres long) which is dead without having breathed.

† Bertillon, *op. cit.*, p. 59.

Proportion of Males and Females at Birth. In 1838–47 the males born to every 1000 females born averaged 1050. Since then the proportion has gradually declined to 1036 in 1891–95. (See tables 3 and 4, *Fifty-eighth Annual Report of the Registrar-General*, 1895.) In registration counties the lowest proportions of male to female births were 974 per 1000 in Cumberland, 981 in Oxfordshire, and 988 in Derbyshire; the highest 1083 per 1000 in Dorsetshire, 1101 in Huntingdonshire, and 1188 in Rutlandshire.

In Berlin in 1895 the proportion of male to female births was 1047 per 1000; in Hamburg it was 1075 in the same year, having increased fairly steadily from 1885, when it was 1032. In previous years the proportion of male births to 1000 female births was higher than this; thus in 1883 it was 1080. In London, on the other hand, the proportion has remained fairly constant, and is lower than in the continental cities; it was 1041 in 1880 and 1036 in 1895.

The proportion of boys to girls at birth is smaller in England than in any European country, and for some unexplained reason the excess in the proportional number of boys is gradually declining. The proportion of males is greater in large than in small families; it is also greater among the earlier born than among the later born infants in a family. According to Bertillon, the last rule does not apply to illegitimate births.

It is interesting to compare the proportion of the two sexes as shown by the census returns and by life-table experience. The following table gives the proportion of males and females at each age-group at the census 1891:—

IN ENGLAND AND WALES THERE WERE AT THE CENSUS 1891 THE FOLLOWING NUMBER OF MALES TO EVERY 1000 FEMALES AT EACH AGE-GROUP.

	Proportion of Males to 1000 Females.	Ages.	Proportion of Males to 1000 Females.
All Ages	940	25–	896
		30–	931
0–	985	35–	945
1–	988	40–	931
2–	993	45–	924
3–	990	50–	901
4–	993	55–	877
		60–	858
Under 5 years	989	65–	832
5–	996	70–	795
10–	999	75 and upwards	732
15–	985		
20–	891		

The results in this table, based on the population as enumerated in 1891, do not correspond with the life-table experience based on the mortality in England and Wales in the ten years 1881–90. In this life-table a million infants, in the proportion of 509,180 males to 490,820 females, are traced from birth through life.

ENGLISH LIFE-TABLE, 1881–90.

Age.	Born and Surviving at each Age (l_x). Males.	Females.
0	509,180	490,820
1	427,184	426,461
2	402,706	403,980
3	393,110	394,689
4	387,062	388,716
5	382,646	384,432

Thus, although at birth the million infants comprise an excess of males, before the end of the second year of life the balance is more than restored, females being in excess.

If, instead of starting in the life-table with males and females in the proportion shown by the birth-returns, we take a million of each sex, then according to the English experience in 1881–90 the males will have been reduced to one-half of their original number between the 51st and 52nd year of life, the females between the 56th and 57th year of life. The differences between the life-table results and the census figures are partially explicable on the ground of errors in the census returns; but are chiefly caused by the higher death-rate and the greater migration among males.

Illegitimacy. Illegitimacy has important bearings on social problems, as well as on the chances of life of infants, and therefore deserves careful consideration.

It may be stated, (1) like the total birth-rate, as a proportion to every 1000 of the population.

(2) The most accurate method is to state it as a proportion to the number of unmarried women living at child-bearing ages. (See p. 72.)

(3) It is often stated as a proportion to the total births. This method is fallacious, as the number of legitimate births varies with the marriage-rate, and this with the activity of trade; so that if the marriage-rate were low, and the number of illegitimate births remained stationary, the amount of illegitimacy would appear larger than usual, when not really so.

Illegitimacy in England. The number of illegitimate births per 1000 of population has varied from a maximum of 2·3 in 1850–52, in 1859 and in 1863–64, to a minimum of 1·3 in each of the years 1890–95. (See tables 3 and 4, pp. xxxviii. and xl. *Registrar-General's Report*, 1895.)

Thus the illegitimate birth-rate has declined along with the decline in the marriage-rate and in the legitimate birth-rate. The table on p. 74 shows how far this comparison may be trusted, and indicates that the reduction in the illegitimate birth-rate between 1881 and 1891 was four times as great as the reduction in the legitimate birth-rate.

For similar reasons it is doubtful how far the comparison between the amount of illegitimacy in the different **counties** of England is trustworthy. Stated as a proportion of illegitimate to legitimate births, the ratio was lowest in Middlesex and Essex in 1895 (29 per 1000), in Monmouthshire (31), South Wales (33), and highest in North Wales (65), Cumberland (70), Herefordshire (72), and Shropshire (74).

It is a remarkable fact that although the mean age at marriage has increased, and the proportion of marriages under age has decreased, the illegitimate birth-rate has likewise decreased.

Illegitimacy in other Countries. The table on p. 64 gives interesting details on this point. The difference in definition of still-births in various countries (p. 80) must be borne in mind.

Judged by the proportion of illegitimate births to population, illegitimacy is much greater in amount in Berlin than in England (see Fig. 4). In 1892–95 the annual illegitimate births averaged 4·2 per 1000 of the population, as compared with 1·3 in England as a whole. A useful comparison may be made between the data in the tables on pp. 64 and 74. The illegitimate birth-rate in England and Wales is stated in terms of the unmarried women aged 15–45, that for other countries in terms of the larger group comprised by unmarried women aged 15–50. Notwithstanding this fact, England stands lowest on the list, having only one-fourth of the amount of illegitimacy of Austria, which occupies the highest position on the list.

The Malthusian Hypothesis. It has not been thought necessary to reproduce the account and criticism of Malthus' *Essay on Population* (1798) which appeared in former editions of this work. The reader wishing to study the subject will find it fully discussed from different standpoints in the following works:—

- *Supplement to the Thirty-fifth Annual Report of the Registrar-General* (Farr, pp. xv.–xx.).
- *Character and Logical Method of Political Economy* (J. E. Cairnes, LL.D. Chapter on Malthusianism. Second Edition, 1875).
- *Population and Capital* (G. K. Rickards, M.A., 1854).
- *On Population* (William Godwin, 1820).
- *Economic Studies* (W. Bagehot, 1880).
- *Progress and Poverty* (Henry George).
- *The Principles of Population and Their Connection with Human Happiness* (A. Alison. 2 vols., 1840).

It may suffice to say here that the problem of increase of population is not urgent, that the forecasts of Malthus and his adherents have hitherto not been realized, and that, although in a few centuries the possibilities of emigration must cease, assuming the same rate of increase of population as at present, this need excite no apprehension in view of the international decline of the birth-rate shown in Fig. 4. In France, and to a less extent in the United States, the failure of the population to grow by natural increase is beginning to cause some apprehension. (See also pp. 17 and 77.)

Natural Increase of Population. The *natural increment* of a population in any year equals the births *minus* the deaths. It may be greater, owing either to a diminished number of deaths or an increased number of births. The *actual increment* is governed also by the balance between immigration and emigration. The approximate amount of emigration from the United Kingdom for a series of years can be seen in Table 32, p. xcviii. *Registrar-General's Report*, 1895.

The population of England and Wales in 1891, as determined by natural increment only, was 29,603,913, as actually enumerated 29,002,525, the difference of 601,388 representing the loss by excess of emigration over immigration. The relationship between natural and actual increment in England can be studied in the table on p. 9.

CHAPTER X.

DEATH-RATES.

MORTALITY statistics surpass all other vital statistics in importance, whether they are considered from a social or actuarial standpoint, or from the standpoint of preventive medicine.

Estimation of Death-rate. The death-rate may be reckoned (1) in proportion to every thousand of the mean population; or (2) the proportion of deaths, taken as unity, to the whole population may be stated. Thus, in 1886 the death-rate per 1000 was 19·3, which is equivalent to 1 in 51.

The two are easily convertible by division.

$$\frac{1000}{51}=19\cdot3.\ \frac{1000}{19\cdot3}=51.$$

The assumption underlying problems of life contingencies is, that the deaths in each year of age are uniformly distributed throughout the year. This assumption introduces an error; but the error, except for the first years of life, is infinitesimal, and in all practical calculations may be disregarded. The ratio between deaths and population is known as the *death-rate* or *rate of mortality*, having been so called by Farr. By actuaries, however, it is known as the *central death-rate*, the name *rate of mortality* being reserved for the probability of dying in one year, q_x (p. 258).

Death-rates for Short Periods. An annual death-rate per 1000 implies the number of deaths that occur among 1000 persons, each supposed to live through a complete year of life. The death-rates for shorter periods are calculated on the assumption that the deaths would have continued in the same proportion during the remainder of the year. It is evident that the shorter the period to which a death-rate refers the greater the liability to error, owing to accidental causes of variation. The death-rate for a short period expresses a fact, the errors only arising when we draw too wide inferences from it. Large fluctuations from accidental causes occur, especially in connection with small populations. A temporarily high death-rate may, for instance, only mean that, owing to the prevalence of inclement weather, a considerable number of unstable and fragile lives have had their deaths slightly hastened.

The *death-rates for each week* in thirty-three great towns published by the Registrar-General are *annual* death-rates per 1000 of the mean population of the year; *i.e.*, they represent the number who would die per 1000 of the population, supposing the same proportion of deaths to population held good throughout the year. They are of service in contrasting with the death-rate of the same place at the corresponding period of a preceding year, and as showing the influence of seasonal variations; but should be received with caution when used to compare one town with another.

The death-rate for a week might be obtained, if there were exactly 52 weeks in a year, by multiplying the deaths by 52, or dividing the population by 52, and then proceeding as for an annual death-rate. But the correct number of days in a natural year is 365·24226, and the correct number of weeks therefore 52·17747. The Registrar-General therefore divides, for the purposes of his weekly returns, the estimated population of each town by 52·17747, thus obtaining what may be called the weekly population of the town. Thus, if the population of a town is 143,956, its weekly population is

$$\frac{143{,}956}{52{\cdot}17747} = 2758,$$

which is assumed to remain constant for the year for which the calculation is required. Now, if there are 35 deaths in one week, then the annual death-rate for the week in question

$$= \frac{35 \times 1000}{2758} = 12{\cdot}69$$

It would be more logical to multiply the deaths of each week by 52·17747 than to deal with the population; but as this would require to be done each week, the former method is evidently less laborious, and produces the same results.

The Registrar-General makes his death-rates *for each quarter* refer to the thirteen weeks most nearly corresponding with the natural quarter; and the quarterly population is obtained by multiplying by thirteen the population of one week.

The death-rate, expressing the proportion borne by deaths from all causes to each thousand of the population, is known as the **general** or **crude death-rate.** The fallacies detracting from its value as a test of relative vitality will be subsequently considered. It should be regarded as the first test, to be followed up by further research. It is doubtful, however, whether, in the case of large populations, any more trustworthy test is available; and its value may be regarded as remaining unimpaired, in spite of numerous attacks upon it.*

Special Death-rates are also employed; and these may be divided into two kinds: (1) those which differentiate the persons affected as to age and sex, race, social condition, occupation, density of population, locality, season, etc.; and (2) those which differentiate the causes of mortality, as the individual zymotic diseases, phthisis, violence, suicide, etc.

We shall discuss in this chapter the influence on the death-rate of movements of the population, of large institutions, of the birth-rate, and of the age and sex distribution of the population.

Effect of Movements of Population. The effect produced by immigration and emigration will vary in accordance with the average age and sex of the migrants. The mortality of most large and growing towns would stand higher than it does but for the large number of young and healthy immigrants from the country. Similarly, watering-places and residential towns appear somewhat healthier than they are, because of the large proportion of young domestic servants.

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* The following weighty cautions by Dr. C. Kelly (*Annual Report West Sussex*, 1896) may be quoted here :—

"Much harm has been done in past years by those who have led the public to believe too much in low death-rates, when the mere fact of a district having such rates ought rather to make one suspect that some source of fallacy must be present. Such sources are to be found readily enough, and they are most frequent in those places which owe some of their prosperity to the common belief. . . .

"It is always well to distrust a very low death-rate, and careful inquiry should be made into the age and sex-distribution of the population before coming to a conclusion.

"In contrasting the figures year by year for the same district the comparison may be made readily and correctly, but when other districts are contrasted one with the other, such a comparison may be fallacious, unless due allowance be made for age and sex distribution." (See Chap. XII.)

In New Zealand the death-rate has varied from 9·10 to 10·29 per 1000 in the years 1887–96, a remarkably low death-rate, if the registration of deaths is fairly complete, for a population which, when enumerated in 1896, amounted to 703,360. Doubtless the population is to some extent a selected one, emigrants to such a distant part of the world being usually robust and healthy. It might be surmised that a large share of the low death-rate of New Zealand is caused by the favourable age-distribution of its population; but the figures do not show that this is a prominent factor in the case. Thus, out of every 1000 enumerated in New Zealand in 1896, 363 were aged 0–15, 583 were aged 15–60, and 54 aged 60 and upwards; while in England at the census, 1891, the corresponding figures were 351, 576, and 73. Nor does any excess of children under five account for the difference between the English and New Zealand death-rate, as in 1891 the population under five per 1000 at all ages was 123 in England, as compared with 119 in New Zealand in 1896.

The bulk of the immigrants into towns are in good health, but a certain number go from the country into urban hospitals.

On the other hand, many townspeople suffering from phthisis or other chronic disease migrate into the country, and aged persons very commonly do the same.

The only way to avoid the fallacies arising from migration would be to have records kept of the movements of population, and the births and deaths of each place subjected to analysis before comparison is made. In order that the death-rates of two populations should be comparable on equal terms, so far as migration is concerned, it would be necessary that (*a*) the number of immigrants and the average duration of their residence should balance the number of emigrants and the average duration of their absence; and that (*b*) the proportion of persons of each sex living at each age, their state of health and liability to disease, should be the same among both.

Such conditions are not attainable even in European States, where a record of migrants is kept, and much less so in this country; and it is satisfactory to remember, therefore, that in most instances the sources of mistake tend to counteract each other; and that the most important fallacy, that arising from varying age-distribution of the population, can be avoided by giving the death-rate separately for different groups of ages.

It is commonly assumed that mortality statistics may be affected by migration in another way. This may be made clear by an example. The high mortality of certain thickly-populated districts was, a quarter of a century ago, explained as being due in part to the fact that, owing to the migration occurring among the labouring-class population of these districts, the same house may in one year represent the accidents, deaths, and diseases of say twenty-four persons, instead of the six persons which the census gives for each house. This assumption was, however, erroneous, for, although the families occupying a single house change four times in a year, the effect of four families in excess of that produced by one family during a whole year is counterbalanced by the fact that it is only operating for one-fourth of the time. Thus, four families occupying a house for three months each will produce the same effect upon the death-rate as one family living in the same house for a whole year, assuming that the numbers in the separate families, their age-constitution, and other conditions of life are identical.

Brighton may be quoted as an instance of a town whose population is, during the greater part of the year, swollen by the ingress of thousands of visitors, of whose number there is no trustworthy estimate, and who yet furnish a considerable quota to its mortality. The census enumerations in April, 1881 and 1891 (which form the basis of calculation of the population for the current year), necessarily included all the visitors present at those dates. There is, however, probably no time of year in which the number of visitors in Brighton is at so low an ebb as in April (when the national census is taken).

The course theoretically least open to objection is *to exclude the estimated population of visitors and all deaths of visitors* in calculating the true death-rate of Brighton. This is, unfortunately, impracticable, both as regards population and deaths, and the death-rate is, therefore, calculated on a population smaller than that from which the deaths are derived.

Effect of Public Institutions. The consideration of the effect which public institutions exert on local bills of mortality naturally follows on a consideration of the effect of migration, as the inequality arising from such institutions is due to migrations into them from outlying districts. The rule in dealing with a public institution is to deduct the deaths of those inmates derived from outside the district concerning which the calculation is made, at the same time including the deaths of inhabitants of the said district which may have occurred in other institutions outside the district. Thus, workhouses and asylums are often situated outside the district from which they receive inmates; and in London and other great towns the large public hospitals receive patients from outlying districts. The deaths in all these cases should be, and in some cases are, relegated to their respective districts..

The following case reproduced from the first edition of this book may be taken as exemplifying the methods of procedure in correcting a local death-rate for extra deaths occurring in external and internal institutions.

The Wandsworth sub-district of the Wandsworth district (London, S.W.) has within its borders the County Lunatic Asylum, the Hospital for Incurables, St. Peter's Hospital, Wandsworth Prison, and the Royal Patriotic Asylum for Girls; and it sends its sick poor to the Wandsworth and Clapham Workhouse Infirmary, which is outside its borders, while some of its inhabitants die in the large metropolitan hospitals.

Total deaths in Wandsworth in 1885 were . . .	628
Of these there occurred in its internal institutions .	132

In addition there occurred in the Union Infirmary and other outlying institutions 78 deaths.

The mean population of Wandsworth in 1885 was 31,497.

(1) The death-rate, uncorrected for deaths in internal institutions, and not including deaths in outlying institutions, is

$$\frac{628 \times 1000}{31,497} = 19{\cdot}83 \text{ per thousand.}$$

(2) In order to ascertain the death-rate corrected for internal institutions without including the deaths in outlying institutions, we must ascertain the *population of its institutions* as well as their *deaths*. By the census of 1881 this was 1482, which may be taken as nearly correct for 1885.

Corrected population $= 31,497 - 1482 = 30,015$.
Corrected deaths $= 628 - 132 = 496$.
$$\text{Death-rate} = \frac{496 \times 1000}{30,015} = 16{\cdot}52.$$

(3) The death-rate excluding the population and deaths of internal institutions, and including the deaths (but not the

population, because this is unknown) of Wandsworth parishioners in outlying institutions.

$$\text{Population} = 30{,}015.$$
$$\text{Deaths} = 496 + 78 = 574.$$
$$\text{Death-rate} = \frac{574 \times 1{,}000}{30{,}015} = 19{\cdot}12.$$

The last death-rate more nearly than any other represents the true mortality of the Wandsworth sub-district. For it excludes the population and deaths in its numerous internal institutions (to which Wandsworth contributes only an inappreciable quota), and it allows for the deaths of Wandsworth parishioners in external institutions. The only fallacy is, that no allowance is made in the population for these inhabitants of Wandsworth who are in the outlying institutions without their illness proving fatal. This number must, however, be comparatively small, and cannot very materially affect the result.

Official Corrections. Each sanitary authority in London is supplied quarterly from the General Register office with particulars of deaths of their inhabitants in outlying institutions, so that the necessary correction can be made.

For the thirty-three great towns, the statistics published by the Registrar-General make corrections to the following extent: the deaths of non-residents are distributed to their respective districts in the case of the following institutions, viz., *County* Hospitals, *County* Asylums, Infectious Diseases Hospitals, and Convalescent Homes. On the other hand, all deaths occurring in general, *i.e.*, Borough as distinguished from County Hospitals, and in children's and other special hospitals, are left undistributed, and are included in the returns of the sub-districts in which those institutions are situate.

The previous residence of persons dying in institutions is in each instance inserted in the death register in order to afford to the medical officer of health the means for obtaining the information necessary to correct the death statistics of his district. It still remains true, however, that in many small urban and rural districts this correction is avoided, and erroneous because defective death-rates are published.

CHAPTER XI.

RELATIONSHIP BETWEEN BIRTH-RATE AND DEATH-RATE.

INFLUENCE **of Birth-rate on Age-Constitution of Population.** The age-distribution of a population, *i.e.*, the relative number of persons living at different groups of ages, depends upon the rate and mode of increase of the population. This increase may be due to excess of births over deaths (natural increase) or to immigration. Immigration is generally of comparatively young adults, and thus has an important bearing on the death-rate, which it tends to lower. A population such as that of England, with a birth-rate persistently higher than the death-rate, contains an undue proportion of children, of youths, and of persons of middle life, and so a lowering of the death-rate is produced, as in the case of immigration. The undue proportion of persons of a lower age in a population with a persistently high birth-rate is explained as follows: In a stationary population undisturbed by migration, the number of births equals the number of deaths, and if the rate of mortality at different ages does not vary from time to time and the births and deaths are uniformly distributed throughout each year, the age-constitution of the population remains uniform. The births and deaths in the stationary population being equal in number, the birth and death-rates are also identical. If now the birth-rate suddenly increases, the number living in the first year of life will increase; and if this higher birth-rate persists, in the second year of its occurrence the number living under two years of age will be increased, in the third year the number living under three years, and so on. If the high birth-rate continues for, say, 40 years, the number living at all ages under 40 will be increased, and so on. But for about twenty of these forty years a further influence will have been brought to bear. Those aged 20-40 who were born under the conditions of the hypothesis have children of their own; so that, assuming the birth-rate to remain stationary, the *absolute number of births* per annum is increasing rapidly every year. The consequence of this uninterrupted increase in the annual number of births is, that the proportion of those living at the earlier ages as compared with the entire population becomes greater, and a distribution of the population is arrived at which we shall find is favourable to a low death-rate (page 96). The diagram on page 94 should be studied in connection with the preceding remarks.

The disturbing effect on the age of a population of a yearly increasing number of births is shown in the accompanying diagram from the supplement to the *Registrar-General's Thirty-fifth Annual Report.*

The diagram represents by its area enclosed by the continuous dark line, the relative numbers of the population in eighteen groups of ages, as enumerated at the census of 1871. The area enclosed by the dotted lower line represents what the population would have been had the births remained uniformly 253,320 a year as in 1771, instead of increasing as they did to 797,428 in 1871. Thus in the population as enumerated in 1871, 3,100,000 were living who were under the age of 5 years, while in the population with the stationary number of births, the number of children of that age would be *one million only*. It is assumed that no migration occurred during the 100 years.

We have assumed in the preceding remarks that the change was from a stationary population to one with a birth-rate higher than its death-rate, but in which the birth-rate remained constant after it had once increased. If, however, the birth-rate were continuously to increase, the effect in disturbing the normal or Life-Table distribution of a population would be still greater, and for many years this was the state of things in England. Since 1876, however, the birth-rate has decreased, and, as shown by the following figures, there was in several years an actual decrease, and since then only a very slight increase in the absolute number of births, irrespective of population. Such a condition of the factors producing population will obviously have a much less disturbing influence on its age-distribution than if the number of births were continuously to increase. If the total annual births were to remain stationary in number, the disturbance in the age-distribution of the population would, as the wave of population advances, gradually disappear.

DIAGRAM OF THE POPULATION OF ENGLAND & WALES AT DIFFERENT AGES AS ENUMERATED IN THE YEAR, 1871.

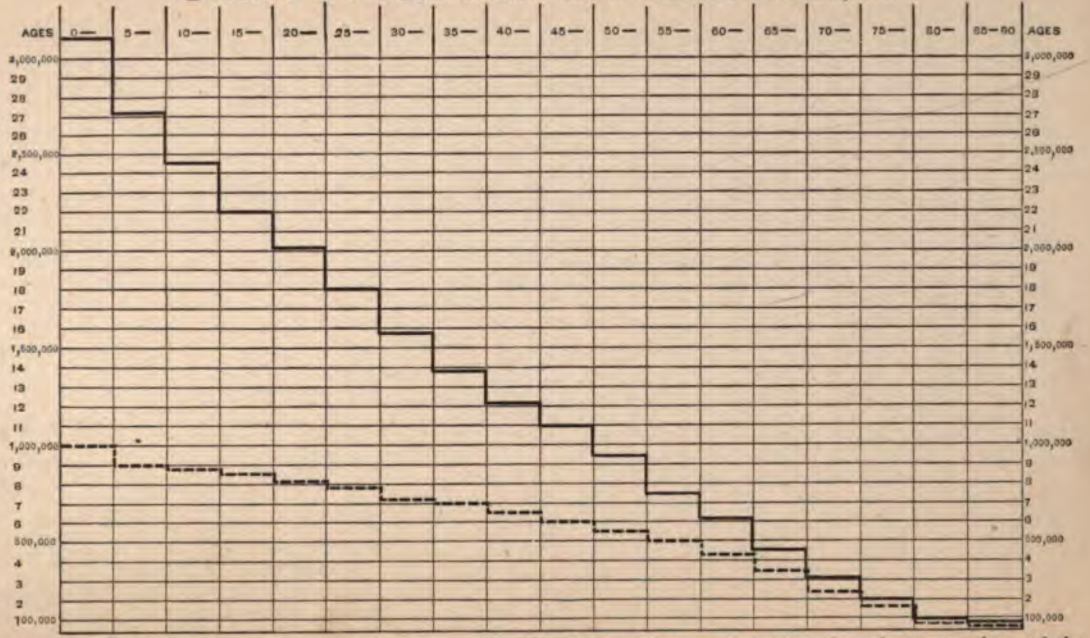

FIG. 5.—The diagram represents by its area enclosed by the continuous dark line, the relative numbers of the population in eighteen groups of ages, as enumerated at the census of 1871. The area enclosed by the dotted lower line represents what the population would have been had the births remained uniformly 253,320 a year as in 1771, instead of increasing as they did to 797,428 in 1871. Thus in the population as enumerated in 1871, 3,100,000 were living who were under the age of 5 years, while in the population with the stationary number of births, the number of children of that age would be *one million only*. It is assumed that no migration occurred during the 100 years.

Year.	Number of Births.	Birth-Rate.
1876 . .	887,968	36·3
1880 . .	881,643	34·2
1881 . .	883,642	33·9
1882 . .	889,014	33·7
1883 . .	890,722	33·3
1884 . .	906,750	33·3
1885 . .	894,270	32·5
1886 . .	903,866	32·4
1887 . .	886,331	31·4
1890 . .	869,937	30·2
1894 . .	890,289	29·6
1895 . .	922,291	30·4
1896 . .	917,201	29·7
1897 . .	921,104	29·7

M. Bertillon gives a valuable table (p. 28, *op. cit.*), from which the following particulars are derived :—

AGE COMPOSITION OF THE POPULATION IN EUROPEAN COUNTRIES IN 1880.

Country.	For every 1000 inhabitants at all ages there were		
	Children. 0–15	Adults. 15–60	Old People. 60 and upwards.
Hungary	373	575	52
Scotland	366	556	78
England	365	562	73
Germany	354	567	79
Ireland	351	553	96
Spain	348	595	57
Norway	347	563	90
Belgium	335	567	98
Sweden	326	581	93
Italy	322	589	89
France	267	610	123

It is evident that, with the exception of Hungary, no European country has so young a population, based on the average age of its people, as have England and Scotland. Probably this remains true, notwithstanding the lowered birth-rate shared by England and other countries in recent years.

The following table, calculated from the English census figures for 1881 and 1891, shows clearly the effect on the age-distribution of the population of the lowering of the birth-rate between the two census enumerations.

AGE COMPOSITION OF THE ENGLISH POPULATION.

	0–15	15–60	60 and upwards	Total at all Ages.
1881 . . .	372	563	65	1000
1891 . . .	351	576	73	1000

Influence of Birth-rate on Death-rate. We have seen that the age-constitution of the population is, if migration be left out of account, determined by the birth-rate. The age-constitution of the population is of fundamental importance in relation to the death-rate, the birth-rate affecting the death-rate only in so far as it alters the age-constitution of the population.

Most erroneous ideas have prevailed as to the relation between the birth-rate and the death-rate. The interpretation of the true relationship between the two depends on an appreciation of what has been said concerning the influence of the birth-rate on the age-constitution of a population. It is evident that if, owing to a high birth-rate, there is a larger proportion of children in one community than in another, and the relative hygienic conditions of the two are equal, there will be more deaths of children in the former; and inasmuch as the rate of mortality of young children is higher than that of all others except the aged, the general death-rate will be raised. But if the high birth-rate be *continued*, there will not only be a large proportion of children, but of others between 10 and 40 years of age, at which ages a low rate of mortality holds; and this factor counterbalances the other, and causes a continued high birth-rate to be associated with a low death-rate. Speaking generally, the mortality of a population in which there is an excess of births over deaths should be lower than that of a stationary population, in which the births and deaths are equal in number, because in the latter case there is a larger proportion of old people than in the former. The only exception to this rule would be if emigration interfered with the normal effect of a high birth-rate.

The late Dr. Letheby held, on the contrary, that "the birth-rate is the controlling element of the death-rate"; that "an increase in the rate of mortality is often a sign of prosperity, for a high death-rate means a high birth-rate, and a high birth-rate is the invariable concomitant of prosperity." According to this view, a high birth-rate is a direct and mechanical cause of a high death-rate, owing to the great mortality among infants. This theory ignores the essential fact that a continuously high birth-rate not only causes an excess of the infantile population, among whom the mortality is great, but also an excess of persons between 10 and 40 years of age, among whom the rate of mortality is low.

That a high birth-rate and a high death-rate commonly co-exist is certain, though the concurrence is by no means constant, nor do the variations in the two follow on equal lines, as can easily be seen by comparing the birth and death-rates of different great towns.

A high birth-rate usually occurs in crowded districts, there being in these a much higher proportion of people at child-bearing ages, owing to the inrush of young workers in search of the higher town wages. It is not surprising that in such conditions of life the high birth-rate should be associated with an excessive infantile mortality and a high general death-rate.

So far from the high birth-rate of towns causing their higher death-rate when compared with rural districts, it will be hereafter shown (p. 108) that in nearly every great town the age-distribution of the population is more favourable to a low death-rate than that in rural districts. The higher death-rate in towns is caused by their less favourable conditions of life, and not by an unfavourable age-distribution of the population.

Low birth-rates and low death-rates also commonly co-exist; but the conclusion that one causes the other is altogether untenable. In France there is a low birth-rate and a high death-rate, owing largely to the fact that the continuous low birth-rate has caused the average age of the population to be considerably higher than in this country. Thus in 1891–95 the mean annual birth-rate in France was 22·4 and the death-rate 22·3 per 1000, as compared with a mean annual birth-rate in England of 30·5 and a death-rate of 18·7 per 1000. The table on p. 113 shows that in 1881 France, out of every 1000 persons, had 171 aged 55 and upwards, as compared with 105 in England. Under the age of 5 there were 92 in France, as compared with 136 in England. Thus the small proportion of young children, which, according to Letheby, ought to have been associated with a low death-rate, was associated with a comparatively high death-rate.

To sum up. Populations having a continuously high birth-rate should (sanitary conditions being equal) have lower death-rates than populations having low birth-rates, because a continuously high birth-rate means an exceptionally large proportion of young adults in a population, and consequently an unduly small proportion of old people. Conversely, a low birth-rate means a small proportion of young adults and a large proportion of adults and old people, and is therefore unfavourable to a low death-rate.

A High Birth-rate and a Low Birth-rate may both be followed by a Low Death-rate. Dr. R. W. D. M. Cameron (*Public Health*, vol. vii. p. 100) has constructed the following diagram to illustrate the direct and immediate increase of death-rate produced by a high birth-rate at its first occurrence (through increase of infantile mortality) and the subsequent decrease of death-rate produced by a continued high birth-rate, through its influence in increasing the proportion of persons living at ages of low mortality.

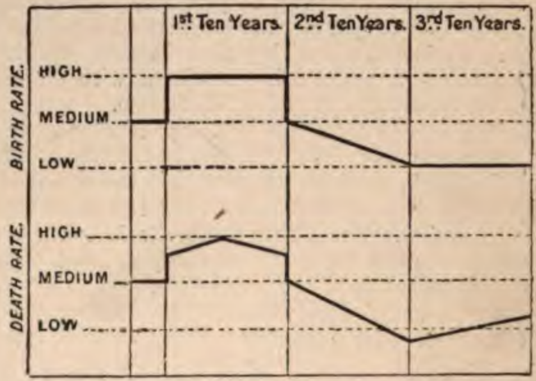

FIG. 6.

Diagram illustrative of relations between birth and death-rates.

In the diagram the birth-rate is supposed to mount up suddenly and continue high for ten years, then to drop from "high" to "medium," go on falling gradually during the second decade, finally remaining uniformly low in the third decade.

The corresponding death-rate rises at once with the birth-rate, reaches its acme near the end of the first five years of high birth-rate, and slowly declines during the second five years. It next suddenly drops along with the birth-rate, continuing to fall with it during the next ten years. In the third decade it gradually rises without any corresponding rise of birth-rate.

During 1881–90 a high birth-rate in the previous decade and a lower birth-rate in the current decade were both co-operating to produce a low death-rate.

A Special Illustration of Relationship between Birth-rate and Death-rate. The following example illustrates the errors as to the relationship between the birth-rate and death-rate which reappear from time to time in local health reports. Dr. Yarrow, the medical officer of health of the parish of St. Luke, a central district in London, in a special report on the birth-rate and death-rate of the parish in 1887–96, endorses Dr. Drysdale's opinion that "if the mortality is to be lowered in St. Luke, births must be reduced." If, as may be assumed, by mortality is meant the general death-rate at all ages, this raises the whole question of the relationship between the birth-rate and the death-rate, and the instance is worthy of detailed study. The deaths in St. Luke under the age of 5 exceed the total deaths at all other ages, which is taken by Dr. Yarrow as "proving beyond doubt that the infant mortality is the main cause of our heavy death-rates." Is this the case?

From what has been said in the previous paragraphs it will be evident that a high birth-rate, if it cause a high death-rate, will do so by increasing the proportion of children under 5 who are subject to a higher rate of mortality than that prevailing at ages 5–55.

What then is the age-distribution of St. Luke's population? The following table shows the number of persons out of 1000 at all ages which, at the census 1891, were of the following ages:—

	England and Wales.	St. Luke.	Kensington.
Under 5	123	130	89
5–55	773	786	808
Over 55	104	84	103
	1000	1000	1000

639347

It has not been thought necessary to further subdivide the groups of ages in the preceding comparison, but if further indications are required they are furnished in the following table. The factors of correction by which the death-rate of each of the above in 1891 must be multiplied (according to the method described on p. 109) are as follows:—

	England and Wales.	St. Luke.	Kensington.
Factor of Correction .	1·0000	1·08070	1·10184
Crude Death-rate . .	21·5	30·1	18·4
Corrected Death-rate .	21·5	32·5	20·3

Thus the age-distribution of St. Luke is more favourable to a low general death-rate than that of England as a whole, though not so favourable as that of Kensington.

St. Luke and Kensington are instances of parishes which have had for a protracted period a high and a low death-rate respectively. In 1861 the birth-rate of Kensington was 30·1; it was 26·9 in 1881 and 23·1 in 1891. The birth-rate in St. Luke, according to the Registrar-General's figures, was 43·3 in 1861, 45·5 in 1881, and 42·9 in 1891. The figures for St. Luke require some correction, as this parish has within it a large lying-in Institution, receiving patients from other districts. When this correction was made for 1897 the birth-rate of 46·7 became 36·3. This correction does not, however, affect the fact that St. Luke has had for many years a relatively high birth-rate. The difference between the low death-rate of Kensington and the high death-rate of St. Luke cannot therefore be caused by any recent or sudden alteration in their respective birth-rates, causing in one a sudden increase of infants, subject as they are to a high death-rate.

Will the steadily higher proportion of children under five in St. Luke's account for its general death-rate being higher than that of Kensington? We will assume, to simplify the argument, that over the age of five the proportion of persons living at each age is identical in both Kensington and St. Luke. This assumption, as can be seen from the first of the preceding tables, favours St. Luke, because, although at the ages of low death-rate 5–55, it has a slightly smaller proportion of persons than Kensington; at the ages of high death-rate, 55 and upwards, it has a much smaller proportion of persons than Kensington. The last factor would tend to counterbalance any advantage that Kensington might secure by an excess of females in its population.

On the basis of the above assumption let the death-rates of Kensington in 1891, at ages under five and over five, be applied to the population of St. Luke in 1891.

	Population of St. Luke, 1891.	Death-rate of Kensington, 1891, per 1000 living at each age-group.	Calculated No. of Deaths in St. Luke.
Under 5 . .	5,529	64·8	359
Over 5 . .	36,911	13·9	513
All ages . .	42,440	18·4	872

Therefore the calculated death-rate in St. Luke would be

$$\frac{872 \times 1000}{42,440} = 20{\cdot}6.$$

But the actual death-rate at all ages was 30·1, the death-rate at ages under five being 97·1, and at ages over five 20·1 per 1000 living at each of these age-groups.

And the general death-rate of Kensington in 1891 was 18·4. It is plain, therefore, that the difference between 20·6 and 18·4 is caused by differences in age-distribution of the populations of St. Luke and Kensington; but that the further difference between 20·6 and 30·1 is caused by differences of social and sanitary conditions, altogether apart from any consideration as to the birth-rate or the age-distribution of the populations.

CHAPTER XII.

DEATH-RATES CORRECTED FOR AGE AND SEX-DISTRIBUTION.

Influence of Age and Sex-distribution on Death-rate. We shall consider in this chapter the means of measuring the modifications in the general death-rate which may result from varying age and sex-constitution of a population, reserving to the next chapter the consideration of death-rates at different ages.

Dr. Ogle has summed up the influence of age and sex-distribution of the population on death-rates in the following words: "It is necessary to point out that two places might be on a perfect equality with each other as regards their climate, their sanitary arrangements, their closeness of aggregation, as also the habits and occupations of their inhabitants, and yet might have very different general death-rates, owing to differences in the age and sex-distribution of their respective populations. Such a supposed case is, of course, scarcely likely to present itself, for when the prevalent occupations are the same in two places the age and sex-distribution is almost certain to be the same also. But in places where the prevalent occupations are not the same there are often very great differences in the age and sex-distribution of the populations, and such as seriously affect the general death-rates."

The age and sex-distribution in a given district varies but slowly, thus little difficulty arises in comparing the death-rate of the same district or town at different periods. It is when different districts or towns are compared that the necessity for correction for age and sex-distribution becomes imperative.

MEAN ANNUAL RATE OF MORTALITY PER 1000 OF EACH SEX.

	Males.		Females.	
	1841–50.	1891–95.	1841–50.	1891–95.
All ages . .	23·1	19·8	21·6	17·7
Under 5 years .	71·2	62·1	61.1	52·0
5– . . .	9·2	4·5	8·9	4·5
10– . . .	5·1	2·5	5·4	2·7
15– . . .	7·1	4·0	7·9	4·0
20– . . .	9·5	5·3	9·1	4·9
25– . . .	9·9	7·2	10·6	6·7
35– . . .	12·9	12·2	12·9	10·3
45– . . .	18·2	19·8	16·1	15·3
55– . . .	31·8	36·3	28·4	29·8
65– . . .	67·5	71·9	60·9	62·8
75– . . .	148·3	149·9	135·9	136·1
85 and upwards	312·3	290·6	293·3	263·8

A study of the above table, giving the death-rate for each sex at various age-groups, shows that between the ages of 5 and 55, the death-rate per 1000 living at each group of ages is lower than the combined death-rate for all ages. Under 5 and over 55, the death-rate is higher than the combined death-rate for all ages. It is evident, therefore, that, as the proportion of the total population living at these different age-groups differs greatly in different communities, the relative numbers subject to the higher death-rates at the two extremes of age will differ to a corresponding extent, and consequently the relative total death-rate for all ages will vary.

The age-distribution of populations is therefore of great importance in determining the relative value of their death-rates. If they are identical in two localities, then any differences in their death-rates may be referred to influences peculiar to each place.

The same reasoning applies for sex distribution. At nearly all ages the death-rate of females is lower than that of males. Consequently an excess of females (as in residential neighbourhoods with a large number of domestic servants) must tend to lower the death-rate of a district, without implying a necessarily better sanitary condition.

CENSUS, 1891.

Ages.	Age-distribution of Population of					
	Huddersfield.		England and Wales.		Norwich.	
	Males.	Females.	Males.	Females.	Males.	Females.
Under 5	475	502	609	616	606	617
5–	491	532	584	587	569	575
10–	534	541	556	556	521	550
15–	513	581	506	513	463	566
20–	474	572	430	483	378	506
25–	782	920	720	787	684	805
35–	583	656	554	592	514	593
45–	413	485	411	450	372	463
55–	250	317	266	306	272	351
65–	119	166	154	188	177	244
75 and upwards	26	48	56	76	64	110
	4660	5340	4846	5154	4620	5380
	10,000		10,000		10,000	

In the above table, and Figs. 7 and 8, which illustrate the same problem, I have compared with England as a whole the two instances among the thirty-three great English towns in which the age and sex-distribution of the population is respectively most and least favourable to a low death-rate. For males it will be seen that under 5, out of 10,000 persons at all ages in the standard or normal population of England and Wales, there were at the 1891 census 609 males, in Huddersfield 475, in Norwich 606; and the corresponding number of female children was 616, 502, and 617 respectively. Norwich therefore had, so far as its children under 5 were concerned, a normal population, while Huddersfield had a population with a very small proportionate number at this age of high mortality.

Over 55 years of age the proportionate number of males in England, Huddersfield, and Norwich respectively, was 476, 395, and 513, and of females 570, 531, and 705. Thus Huddersfield again had the lowest proportion at ages over 55 (ages of high mortality) of both males and females, while Norwich at the same ages had a higher proportion of males, and a much higher proportion of females than England and Wales as a whole.

The problem is to find a means of correcting the death-rate for such variations in age and sex-distribution of the population as are shown in the preceding instances. It can be effected in two ways.

(1) The method to be described on page 109; and

(2) A statement of the deaths at various groups of ages, and in the two sexes, in proportion to the population in each of these age and sex-groups.

The distribution of the population as to age and sex favours a low mortality—

(1) In newly-settled communities.

(2) In towns, and especially when they are rapidly increasing; and

(3) In manufacturing as compared with agricultural neighbourhoods.

The high mortality which usually holds in such populations would be still higher but for their favourable age and sex-constitution.

Dr. Ransome gives an example which may serve as a further illustration of differences in the general death-rate, due simply to varying age-distribution of population. Suppose two towns, *A* and *B*, each with 1000 inhabitants, and exactly alike in their sanitary conditions. *A* has 150 children under 5; *B* has only 100 under 5, which in each case die at the rate of 10 per cent. per annum, while persons over 5 die at the rate of 10 per mille. Reckoning up the total mortality per 1000 at all ages, we find that

In *A*, out of 150 children, 15 die.

" " 850 over 5, 8·5 die; equal to 23·5 per 1000 of the entire population.

In *B*, out of 100 children, 10 die.

" " 900 over 5, 9 die; equal to 19·0 per 1000.

Thus there is a difference of 4·5 per 1000 in the death-rate, due simply to differences in the composition of the two populations, and apart altogether from their state of health.

Dr. Ransome further points out that a death-rate of 10 or even 12 per 1000, which is not infrequently recorded in certain favoured districts, cannot be regarded as a true measure of longevity of its inhabitants. A death-rate of 10 per 1000 means either that every child born attains the age of 100 before he dies, or else that the average age at death is 100, and that if some die in infancy, others must have lived much more than 100. Similarly, a death-rate of 12 per 1000 means an average age at death of over 80. "Under present conditions such figures are not attained by any community in the world, and can only be looked for in the millennium, when, as Isaiah says, the child shall die an hundred years old."

Method of Correction for Age and Sex-distribution. The Registrar-General commenced, in his Annual Summary for 1883,

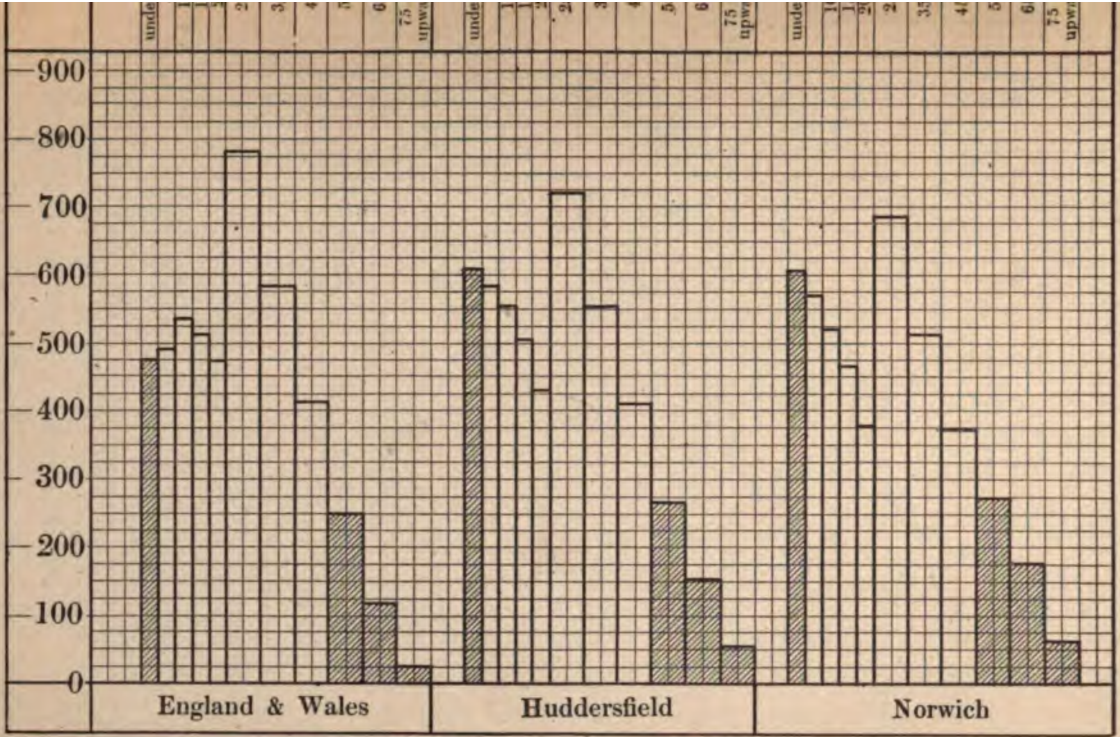

FIG. 7.—Number of Males out of 10,000 at all Ages and of both Sexes, at each Age-period in 1891.
Huddersfield should be in same position as in Fig. 8.

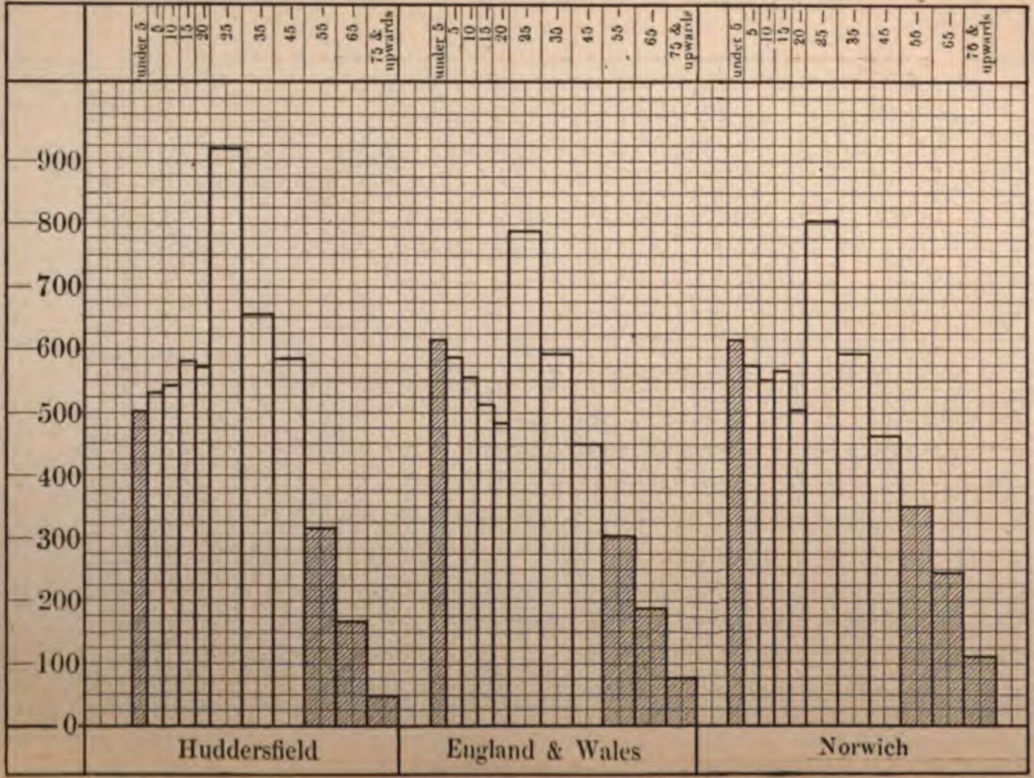

Fig. 8.—Number of Females out of 10,000 at all Ages and of both Sexes, at each Age-period in 1891.

the following method of correcting the death-rates in the great towns, giving in parallel columns the recorded and corrected death-rates for each town. This has been continued for subsequent years, and I append the table for 1897, the towns being arranged in the order of their corrected death-rates.

RECORDED AND CORRECTED DEATH-RATES PER 1000 PERSONS LIVING IN 33 GREAT TOWNS IN 1897.

Towns, in the order of their Corrected Death-rates.	Standard Death-rate.	Factor for Correction for Sex and Age Distribution.	Recorded Death-rate, 1897.	Corrected Death-rate, 1897.	Comparative Mortality Figure, 1897.
Cols.	1.	2.	3.	4.	5.
England & Wales	19·15	1·0000	17·43	17·43	1000
England and Wales, less the 33 Towns .	19·45	0·9845	16·52	16·26	933
33 Towns .	17·71	1·0813	19·10	20·65	1185
Croydon . .	18·37	1·0424	13·07	13·62	781
Brighton . .	18·94	1·0110	15·06	15·23	874
Portsmouth .	18·73	1·0224	16·21	16·57	951
Cardiff . .	17·16	1·1159	14·94	16·67	956
West Ham .	17·75	1·0788	15·66	16·89	969
Swansea . .	17·53	1·0924	15·82	17·28	991
Derby . .	17·36	1·1031	16·03	17·68	1014
Bristol . .	18·33	1·0447	17·20	17.97	1031
Norwich . .	19·99	0·9579	18·77	17·98	1032
Halifax . .	17·20	1·1133	16·48	18·35	1053
Plymouth . .	19·70	0·9720	19·04	18·51	1062
Huddersfield .	16·47	1·1627	16·40	19·07	1094
Leicester . .	17·64	1·0855	17·66	19·17	1100
London . .	17·97	1·0656	18·19	19·38	1112
Hull . .	18·23	1·0504	18·56	19·50	1119
Gateshead . .	17·83	1·0740	18·28	19·63	1126
Bradford . .	16·73	1·1446	17·45	19·97	1146
Birkenhead .	17·42	1·0993	18·26	20·07	1151
Nottingham .	17·81	1·0752	18·78	20·19	1158
Sunderland .	18·25	1·0493	19·70	20·67	1186
Newcastle . .	17·58	1·0892	19·09	20·79	1193
Blackburn .	17·05	1·1231	19·50	21·90	1256
Oldham . .	16·72	1·1453	19·18	21·97	1260
Leeds . .	17·28	1·1082	19·88	22·03	1264
Burnley . .	16·67	1·1487	19·51	22·41	1286
Wolverhampton	18·30	1·0464	22·05	23·07	1324
Sheffield . .	17·22	1·1120	21·20	23·57	1352
Birmingham .	17·33	1·1050	21·59	23·86	1369
Bolton . .	16·90	1·1331	21·97	24·89	1428
Manchester .	16·90	1·1331	23·10	26·17	1501
Liverpool . .	17·44	1·0980	24·37	26·76	1535
Preston . .	17·42	1·0993	24·36	26·78	1536
Salford . .	17·03	1·1244	23·91	26·88	1542

In the preceding table the *Standard Death-rate* signifies the death-rate at all ages, calculated on the hypothesis that the rates at each of twelve age-periods in each town were the same as in England and Wales during the ten years 1881–90, the death-rate at all ages in England and Wales during that period having been 19·15 per 1000.

The *Factor for Correction* is the figure by which the recorded Death-rate should be multiplied in order to correct for variations of sex and age-distribution.

The *Corrected Death-rate* is the recorded death-rate multiplied by the Factor for Correction.

The *Comparative Mortality Figure* represents the Corrected Death-rate in each town, compared with the Recorded Death-rate at all ages in England and Wales in 1897 taken as 1000.

The figures in this column may be read as follows: After making approximate correction for differences of age and sex-distribution, the same number of living persons that gave 1000 deaths in England and Wales in 1897 gave 781 in Croydon, 874 in Brighton, etc., etc., and 1542 in Salford.

The first column in the preceding table is obtained by assuming that the mean mortality in England and Wales in 1881–90 held good in each town. The age and sex-distribution of each town at the last census being known, the mean mortality in England and Wales, 1881–90, is applied to the population thus constituted, and we have as a result the series of death-rates in column 1. The differences between the various towns in this column are consequently caused simply and solely by difference in age and sex-distribution. As an example of the method of obtaining these *standard death-rates* Huddersfield may be taken (see table on following page).

Here the total population of Huddersfield in 1891 = 95,420
The total number of calculated deaths = 1,572
The standard death-rate is therefore

$$\frac{1572 \times 1000}{95,420} = 16\cdot47 \text{ per } 1000,$$

which corresponds with the rate given in the table on p. 108.

Now the annual death-rate of England and Wales in 1881–90 was 19·15. This ought to be the same as the calculated death-rate for Huddersfield, which has been obtained by applying the mean annual death-rate of England and Wales at the different age-groups to the population of Huddersfield at these age-groups.

Ages.	Mean Annual Death-rate in England and Wales 1881–90 per 1000 living at each group of ages.*		Population of Huddersfield in 1891.		Calculated number of Deaths in Huddersfield.†	
	Males.	Females.	Males.	Females.	Males.	Females.
Under 5	61·59	51·95	4551	4785	280	249
5–	5·35	5·27	4691	5081	25	27
10–	2·96	3·11	5113	5165	15	16
15–	4·33	4·42	4905	5549	21	25
20–	5·73	5·54	4541	5461	26	30
25–	7·78	7·41	7466	8834	58	65
35–	12·41	10·61	5576	6265	69	66
45–	19·36	15·09	3944	4649	76	70
55–	34·69	28·45	2393	3017	83	86
65–	70·39	60·36	1128	1590	79	96
75 and upwards	162·62	147·98	250	466	41	69
			44,558	50,862	773	799
Totals			95,420		1572	

* The death-rates for England and Wales are the means of the annual death-rates in 1881–90 (*Registrar-General's Fifty-fourth Annual Report*, Tables 11 and 12.)

† The "calculated deaths" are taken to whole numbers only.

But the death-rate for Huddersfield is *lower*, as shown above, which must arise from the fact that the distribution of age and sex in the Huddersfield population is more favourable than in the country generally. That this is so can be seen from the table on p. 104 and by a glance at figures 7 and 8.

The standard death-rate being lower for Huddersfield must be raised in a certain ratio in order to bring it into comparison with the death-rate of England and Wales—*i.e.*, it must be increased in the proportion of 16·47 to 19·15. But the fraction $\frac{19{\cdot}15}{16{\cdot}47}=1{\cdot}1627$. This, then, is the *factor* for correction for age and sex-distribution by which the recorded death-rate of Huddersfield must be multiplied in order that it may be comparable with that of England and Wales. It may be objected that the mean age and sex-distribution of the decennium 1881–90 is assumed in the above calculation to hold good for every year of the succeeding decennium. This, however, can be proved to be approximately accurate, inasmuch as in populations whose chief occupations remain the same the age and sex-distribution do not alter greatly in a single decennium. It may be objected again that the factor or correction figure, which is accurate when applied to the rate of an entire decade, may not be equally accurate for each year of that decade. But on selecting for comparison two years, one extremely hot and therefore dangerous to the young, and the other extremely cold and dangerous to the aged, the Registrar-General found that the error due to the use of the decennial correction figure as a constant, instead of a special correction figure for each year, was so small that it might practically be disregarded.

By multiplying the recorded death-rates in column 3 (p. 108) by the factors for correction, we obtain the corrected death-rates given in column 4. These are the death-rates which would have been recorded in each town had its population been identical, so far as age and sex-distribution are concerned, with the population of England and Wales.

Trustworthiness of General Death-rates. The following remarks of the Registrar-General (Annual Summary, 1883) on this point are apposite: "It may naturally be asked, of what use are the general death-rates, as usually given, if they cannot be accepted without further and considerable correction? In the first place, if the death-rate in any given town or other area in one year be compared with its death-rates in other years, no correction is required; for the age and sex-distribution in an individual town or other area remains practically constant; and, secondly, although it is doubtlessly true that the general death-rates of towns or other areas cannot safely be used for accurate comparison between such towns or areas in respect of healthiness without further correction, yet they serve as a very valuable approximate indication; for if the column 3 be compared with column 4, it will be seen that whether the towns be arranged according to their recorded or according to their corrected death-rates, the order will scarcely be changed. The correction simply alters the amount of difference between the towns, leaving the position in which they stand to each other but slightly changed."

Instances of Necessity for Correction. In the table on p. 108 it will be seen that only in two of the thirty-three towns, Plymouth and Norwich, is the corrected death-rate lower than the recorded death-rate. In all the other towns a correctional addition to the recorded death-rate is required, varying in amount from 0·17 to 3·07.

This fits in with the general rule that in *rural districts* the age and sex-distribution of the population is less favourable to a low crude death-rate than that in urban districts. In the administrative county of West Sussex the factor of correction, calculated by Dr. Kelly, is ·92205, and the crude death-rate of 13·27 in 1897 becomes 12·24. In 1871–80 the mean annual death-rate in London and Lancashire, taken by Dr. Ogle to represent the urban population, was 23·69 per 1000, while the rate in twelve rural counties was 19·14. But had the rural population had the same age and sex-distribution as was the case in the urban population, its general death-rate would have been only 16·33. Thus the true comparison between urban and rural death-rates should have been between 23·69 and 16·33, and not between 23·69 and 19·14. (*Bulletin de l'Institut International de Statistique, tome* vi. p. 83.)

In *health-resorts* the amount of correction required is usually greater than in the great towns, the constitution of the population being extremely abnormal. Brighton, one of the great towns, is an exception to this rule, and Worthing and Littlehampton, the factors of correction of which have been calculated by Dr. Kelly, are even more remarkable exceptions. With the exceptions mentioned, the following factors of correction have been calculated by me:—

Name of Town.	Population estimated in the middle of 1897.	Factor of Correction.	Death-rate, 1897.	
			Crude.	Corrected.
Brighton . . .	121,401	1·0110	15·1	15·3
Hove . . .	34,331	1·0542	13·7	14·4
Eastbourne . .	46,698	1·1248	8·2	9·2
Margate . . .	—	1·1363	—	—
Bournemouth . .	58,820	1·1368	10·1	11·5
Worthing . . .	20,100	·99300	13·5	13·4
Littlehampton . .	5,800	·99871	12·2	12·2

Dr. Tatham (*Supplement to Fifty-fifth Annual Report Registrar-General*, part i. p. xxxviii.) instances ten urban districts, in all of which the crude death-rate was about 19·8 per 1000, but in which the rates, when adjusted for differences of age and sex-constitution of population, were found to range between such extremes as 16·6 per 1000 (Bridge), and 21·9 (Dewsbury). In the same volume are given the crude and corrected death-rates for males and females in every registration county of England and Wales. In commenting on this subject, Dr. Tatham remarks: "It is futile to compare the crude death-rates of different districts unless their populations are known to be alike with respect to age and sex-constitution."

From an *international* standpoint, corrected death-rates are also of great importance, and it is unfortunate that but scanty data are available. The following instance of the extent of correction required is given by Dr. Ogle. In 1881 the general death-rate in England and Wales was 18·9 per 1000 of all ages, while the general death-rate in France was 22·0, *i.e.*, 3·1 higher than England. But had the age distribution of the French population been identical with that of the English population, the French general death-rate would have been 20·9, and not 22·0. Thus of the 3·1 difference between the two rates, 2·0 was due to difference of health condition, and 1·1 was due to differences of age-distribution.

Dr. Ogle, at the meeting of the International Institute of Statistics in Vienna, 1891, proposed the establishment and international use of a Standard Population, with fixed age and sex-distribution in the calculation and comparison of marriage, birth, and death-rates. He gives in his paper a comparative table of the age and sex-distribution of the population in England and Wales (1881), Austria (1880), Switzerland (1880), Germany (1880), Holland (1879), France (1881), and Italy (1881), from which the following particulars are taken :—

Ages.	Age and Sex-distribution of Population per 10,000.							
	England and Wales (1880).		Germany (1880).		France (1881).		Aggregate of the above seven European Countries.	
	Males.	Females.	Males.	Females.	Males.	Females.	Males.	Females.
0– 5 . .	677	679	685	681	466	458	617	611
5–10 . .	604	608	572	573	459	451	541	537
10–15 . .	540	539	519	516	425	415	491	485
15–20 . .	488	492	465	471	436	431	460	466
20-25 . .	428	468	421	437	437	468	427	447
25–35 . .	701	759	691	726	698	681	700	725
35–45 . .	546	587	577	609	665	654	606	625
45–55 . .	398	439	430	465	566	577	472	499
55–65 . .	278	312	326	365	447	457	358	381
65–75 . .	150	178	166	190	276	290	194	209
75–85 . .	50	64	49	57	100	112	63	70
85 & upwards	6	9	4	5	13	18	7	9
All ages .	4866	5132	4905	5095	4988	5012	4936	5064
	10,000		10,000		10,000		10,000	

Applying the death-rates at each age-period in England and Wales in 1881 to the several populations, and adding up in each case the numbers of deaths among males and females at each age-period, Dr. Ogle found that with identical death-rates at each age and in each sex, the general death-rate—that is, the death-rate as usually calculated—would be :—

18·88 per 1000 in England and Wales.
18·82 ,, ,, Austria.
19·38 ,, ,, Switzerland.
19·21 ,, ,, Germany.
20·18 ,, ,, Holland.
21·31 ,, ,, France.
19·33 ,, ,, Italy.

Dr. Ogle remarks, "Were these death-rates put before the general public, they would scarcely escape falling into serious error, for they would almost certainly ascribe to difference of healthiness differences merely due to the different composition of the populations in regard to age and sex." To avoid this, Dr. Ogle proposed that the population in the preceding table representing the aggregate population of seven European states (about 170 million persons) should be taken as a standard for general international use.

Dr. Körösi of Budapesth adopts Sweden as his standard population, and employs a distribution of ages only,* dividing the population into four periods only, viz. :—

All under one year.
One to twenty years.
Twenty to fifty years.
All over fifty years.

This does not appear to admit of such exact correction for age-distribution as the population proposed by Dr. Ogle, and makes no correction for sex-distribution. The classification of ages is unsatisfactory, in view of the tendency for the ages of persons both at the census and in the death-returns to be entered in round numbers at each decennial period (see figure 1, page 3); and it is doubtful if the subdivision of ages is sufficient to ensure accuracy.

The subject of correction for age and sex-constitution of population will require further consideration in connection with special causes of mortality (pp. 188 and 215), and with the fatality from various diseases (p. 338).

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* Mortalitäts Coefficient u. Mortalitäts Index, Berechnung des Internat. Sterblichkeits Indexes für 14 Staaten, J. Körösi, *Int. Statist. Bulletin* 6, 1892, p. 305.

CHAPTER XIII.

MALE AND FEMALE MORTALITY AT DIFFERENT AGES.

IN the last chapter, the disturbing influence of varying age and sex-distribution of the population on the general rate of mortality has been discussed, and the method by which the fallacy involved can be avoided has been described.

Death-rate at Age-periods.—A statement of the death-rate at various groups of ages per 1000 living at these ages, is also quite trustworthy for comparison with other towns and districts. To obtain this, it is necessary to know—

1. The population at different age-groups.
2. The deaths at different age-groups.

The latter are obtained from the local registrar's death-returns; the former may be ascertained in the case of each urban and rural sanitary authority by an application to each group of ages of the same method of estimation for increase of population as that described on page 6. It is assumed that the rate of increase of population in each age-group is the same as holds good for the total population at all ages. Thus, if the numbers living at each age-group in 1881 and 1891 are known from the census returns, the calculation is short. If the age-constitution of the population in question at the 1881 census is unknown, the following method will give an approximately accurate result. It is assumed that the age-distribution does not vary between the two census enumerations, an assumption approximately correct when the prevailing industry in a given neighbourhood has not altered. Then the total population in 1881 and in 1891, and the population distributed according to age and sex in 1891 being given, the finding of the distributed population of 1896 is a mere question of proportion.

Thus, if the total population of a town in 1891 is 107,546, and the number living aged 10–15 is 10,741, while the total population in 1881 is 92,481, to find the number living aged 10–15 in 1896, the calculation will be in three stages.

(1) Find the rate of increase per unit of population from 1881 to 1891.

$$92{,}481(1+r)^{10}=107{,}546.$$

Therefore $\log.\ (1+r)=\frac{1}{10}\ (\log.\ 107{,}546-\log.\ 92{,}481)$.

Therefore $1+r=1{\cdot}015$.

Where $r=$ rate of increase per unit of population $={\cdot}015$.

(2) Find from this the total mean population for 1896, *i.e.*, after a lapse of $5\frac{1}{4}$ years. If P = mean population of 1896.

$$P=107{,}546\ (1{\cdot}015)^{\frac{21}{4}}.$$

Hence $P=116{,}363$.

(3) Find in this population the number living aged 10–15.

If $x=$ this number,

Then $107{,}546 : 116{,}363 :: 10{,}741 : x$.

Therefore $x=11{,}625$.

There are *two false methods* of estimating the rate of mortality at different ages. The first of these is to calculate the proportion of deaths to total deaths; and the second to calculate the proportion of deaths at various age-groups to the population at all ages. The fallacy involved in the first method arises from the fact that either a diminution in the total deaths or an increase in the deaths at any age-group would increase the proportional deaths at the age group under consideration, though its interpretation in the two cases would be essentially different. Or if a reduction in both the total deaths and the deaths at a given age-group occurred, this reduction might be entirely hidden by the statement of the result as a proportion between the two.

The second method is equally fallacious; as apart from any conditions adverse to health, the number of deaths at various age-groups, and therefore the proportion of these to the entire population, will vary with the number living at the same age-groups.

For *small populations* a too minute division of age-groups is unadvisable. Deductions from a small number of individual facts are seldom so trustworthy as when the basis on which an inference is founded is wider, and accidental causes of variation are thus to a large extent eliminated.

The tables on pp. 103 and 110 give the death-rates at various age-groups per 1000 living at these age-groups at various periods.

It will be seen that under 5 and over 55 the death-rate per 1000 living at each group of ages is higher than the general death-rate at all ages; while at ages between 5 and 45 the mortality in both sexes is lower than the general death-rate, being at its lowest ebb between 10 and 15, and much lower between 5 and 25 than at succeeding ages. It is evident, therefore, that the age-distribution which would be most favourable to a low mortality is one containing an undue proportion of persons aged 5 to 25—such a population as would naturally arise from a continuously high birth-rate. Between 45 and 55 there is a difference between the two sexes. In 1891–95 among men aged 45–55 the death-rate was 19·8, identical with that for all ages; among women aged 45–55 the death-rate was 15·3, or 2·4 per 1000 below that for females of all ages.

Infantile Mortality will be separately discussed in the next chapter.

Death-rates at other Age-periods. The tables on pp. 103 and 110 and figures 8 and 11 should be studied, and the remarks on the death-rate at different ages on p. 103. The death-rate of children under 5 years of age, which, like all other rates, should be calculated on the number of persons living at these ages, forms, probably, a more important hygienic test than the death-rate at any subsequent age-period. The changes which have occurred between 1846 and 1896 in the death-rate at different age-groups in the two sexes may be studied in Tables 13 and 14 of the *Registrar-General's Annual Report.*

Dr. Farr adopted a quinquennial grouping of ages before 25, and after this age a decennial, odd figures being selected as the limiting ages of the groups (25–35, etc.). This method was adopted in order to avoid the fallacy caused by the tendency which both the census and death-returns show to state ages at round figures as 20, 30, etc. It might be supposed that smaller groups of years would give more valuable results; but in view of the preceding consideration, the elaboration of groups would evidently tend to diminish the true value of the results obtained. Dr. Farr states the case against further differentiation of groups thus: "In exhibiting such an abstract, I should commit a fault which I deem it most important to avoid—that of assuming the delusive appearance of more minute accuracy than actually exists."

Effect of Sex on Mortality. The table on p. 103 shows that female mortality was lower than male mortality at all ages except 5–20 in the years 1891–95.

At the ages 5–10 and 15–20 the two sexes had an equal death-rate. Between 10 and 15 female was slightly higher than male mortality.

The dangers connected with child-bearing do not prevent the general female mortality at child-bearing ages from being lower than that of males.

From what has been stated, it will be evident that an excess of females, at any ages except 5–20, would tend, though but slightly, to lower the general rate of mortality. Residential towns and watering-places appear slightly healthier than they are, owing, among other reasons, to the large proportion of domestic servants at ages when they are least prone to illness and death. The female death-rate is generally lowest in the towns in which the excess of the female population is greatest.

The comparative crude death-rates of males and females for successive groups of years are shown in the following table:—

DEATH-RATE AT ALL AGES OF MALES AND FEMALES (ENGLAND AND WALES).

Years.	Males.	Females.
1838–40 . .	23·3	21·5
1841–50 . .	23·1	21·6
1851–60 . .	23·1	21·4
1861–70 . .	23·7	21·4
1871–80 . .	22·7	20·1
1881–90 . .	20·3	18·1
1891–95 . .	19·8	17·7
1896 . .	18·1	16·1

Thus between 1841–50 and 1891–95, the death-rate of males has declined to the extent of 14·3 per cent., and of females, 18·1 per cent. We have already seen that the proportion of boys to girls at birth in the English population is steadily declining (p. 81), and that even in the first year of life the prospects of life in the female are superior to those in the male.

It might be inferred that inasmuch as (*a*) the proportionate number of males with their higher rate of mortality is diminishing in the population, and (*b*) the female death-rate is decreasing at most ages more rapidly than the male, the recent improvement in general mortality is due to these causes, and not to an improvement of the condition under which the male population lives. As shown in the above table, the difference between the male and female death-rates in 1891–95 was 2·1. The disturbing influence of sex-distribution on the general death-rate might therefore conceivably be considerable. If we imagined the entire population to consist of females, without any alteration in conditions of life, the death-rate would become 17·7 instead of 19·8. The excess of female population actually present in any district has, however, only a comparatively small influence on the general death-rate, and such errors as exist can easily be rectified by the method of correction for age and sex-distribution already described (p. 109).

POPULATION AT CENSUS 1891.

		Under 5.		5–55.		55 and upwards.	
Number at each age out of 1000 at all ages in both sexes.	Male	61	...	376	...	47	=1000
	Female	62	...	397	...	57	
Number at each age out of 1000 of each sex.	Male	126	...	777	...	97	=1000
	Female	120	...	769	...	111	=1000

The preceding table shows the variation in age composition of the two sexes. Among females there is a much larger proportion of very aged persons and a smaller proportion of young children than among males. For this reason, in a strictly accurate comparison between the sexes, it is necessary to calculate, by means of the rates at the successive age-periods, the mortality in a **standard million** of population. The standard million adopted (*Supplement to Fifty-fifth Report of the Registrar-General*, part i. p. xxxvii.) is a million having the age-distribution of the entire country in 1881–90. The mean population in 1881–90 is reduced to an average million of persons constituted as follows:—

Age.	Males.	Females.
0– . . .	64,122	64,557
5– . . .	59,333	59,673
10– . . .	54,806	54,765
15– . . .	49,720	50,287
20– . . .	42,922	47,564
25– . . .	71,131	77,499
35– . . .	55,095	58,944
45– . . .	40,472	44,478
55– . . .	27,151	30,893
65– . . .	15,184	18,326
75 and upwards .	5,591	7,487
All ages . . .	485,527	514,473
	1,000,000	

The *causes of the higher mortality among men* are largely connected with the greater hardships and dangers of their occupations. These will be fully discussed in Chapter XVII. The greater amount of intemperance among men has no inconsiderable influence in the same direction.

CHAPTER XIV.

INFANTILE MORTALITY

INFANTILE POPULATION. In considering the mortality at different ages, the first group of ages (under 5) requires further consideration, and especially the mortality under one year of age (infantile mortality). In order to ascertain the infantile mortality, it is necessary to know the infantile population. And in this case the census enumerations do not give us trustworthy information. The ages of infants are very commonly incorrectly returned at the census. The number under one year old is certainly understated (many in their first year being returned as one year old). A smaller number in their second year are returned as two years old, and so on. It has been sought to explain the deficiency of infants returned at the census by omissions in enumeration, but Dr. Farr has attributed it rightly to confusion between the current year of age and the completed years of life, rather than to actual omissions. On account of this deficiency in the census number of infants, it is preferable to estimate their *mortality in proportion to every thousand births.* A more strictly correct plan would be to take the mean of the births of the current and the immediately preceding year as giving the true infantile population; but as this plan is not usually adopted, for the sake of uniformity the births of the current year are taken.

Infantile Mortality. The infantile mortality then is the annual number of deaths of infants under one year of age to every thousand births during the same year. The rate of infantile mortality is regarded as a most reliable test of the sanitary condition of a district, owing to the fact that migration does not greatly affect the result at this early age. If the "sanitary condition" be regarded as including the complex conditions comprised in differences of social status, this is doubtless correct. Dr. Rumsey held that premature births should be struck out of account both of the living and dying. It should be remembered that still-births are in this country excluded from registration, though in France they are included. The best plan would be to insist on registration in every case, making a class separate from births and deaths, in which still-births and possibly premature births would find a logical place.

The infantile mortality in 1896 in England and Wales was 147·5 per 1000, and corresponded almost exactly with the mean rate in the preceding ten years. In registration counties the infantile mortality in the ten years, 1885–94, ranged from 98 in Dorsetshire, 104 in Wiltshire and Westmoreland, and 109 in Berkshire, to 153 in London, 157 in Durham, 161 in Staffordshire, and 170 in Lancashire. Among the great towns in 1897 it ranged from 131 in Huddersfield, and 135 in Croydon, to 220 in Burnley, and 262 in Preston. In London it was 159, as compared with an average of 155 in the ten preceding years. That the differences in infantile mortality are not casual is shown by their repetition year after year, the general rule being that the rate is highest in mining districts and those with textile industries, and lowest in purely agricultural districts.

Mortality of Infants in each Month of First Year. Life is most liable to perish in its earliest stages, "the liability decreasing in something like geometrical progression until the body becomes developed and the reproductive function is established, when the chances of destruction again increase, the succession of the species being thus secured" (Rumsey). With each week after birth the danger of death diminishes. For this reason it is advisable in dealing with large populations to state the monthly or even weekly mortality of infants. The rate of mortality of boys in every month of the first year of life exceeds that of girls, so that, in spite of the much larger number of boys at birth, they are fewer in number than girls at the end of the first year.

In the *Fifty-fourth Annual Report of the Registrar-General* (1891) is a very important discussion of infantile mortality. This embodies the experience of infantile mortality in three selected towns—Preston, Leicester, and Blackburn—which almost invariably occupy the highest position in infantile mortality, of five mining or industrial counties—Staffordshire, Leicestershire Lancashire, W. Riding, and Durham,—and of three agricultural counties—Hertfordshire, Wiltshire, and Dorsetshire.

INFANTILE MORTALITY, 1889-91.

Age.	Of 1000 born, the Numbers surviving at each Age.			Annual Death-rates per 1000 living in each successive interval of Age.		
	Three Rural Counties.	Five Mining and Manufacturing Counties.	Three Selected Towns.	Three Rural Counties.	Five Mining and Manufacturing Counties.	Three Selected Towns.
At Birth .	1000	1000	1000	213	331	382
3 Months	948	921	909	75	154	240
6 ,,	931	886	856	61	128	180
12 ,,	903	831	782	—	—	—

The differences in the death-rates and survivals at each period of three or six months speak for themselves.

The same report contains an infantile life-table for the preceding three rural counties and three towns (p. xii). From this it can be gathered that the mortality is highest in the first day of life, and then falls rapidly, though still high in the remaining days of the first week. The mortality falls enormously in the second week, remains at nearly the same level through the third, and shows a considerable decline in the fourth week. In the second month the mortality is only a small fraction of that in the first month; it then falls more gradually to the end of the seventh or eighth month, after which but little change occurs. Comparing the town rate with the rural rate, in the whole year 218 deaths occur in the former, and only 97 in the former out of 1000 births. This higher death-rate holds good throughout the entire year. Furthermore, it is in the later months that the chief excess of mortality occurs in the urban rates. Thus, in the first week of life the town rate exceeds the rural rate by 23 per cent., in the second week by 64 per cent., in the third week by 83 per cent., and in the fourth week by 97 per cent. Similarly in the first month the town rate is 27 per cent. above the rural rate, in the second month 121 per cent. above it; the excess going on increasing until in the sixth month it amounts to 273 per cent., its highest point, though the excess does not decline to a much lower point throughout the rest of the year.

Healthy District Experience of Infantile Mortality. Since the *Fifty-fourth Annual Report of the Registrar-General* appeared, the chief contents of which relating to infantile mortality have been summarized in the preceding paragraph, the *New Healthy District Life-table*, by Dr. Tatham, has been published (*Supplement Fifty-fifth Report of the Registrar-General*, part ii. p. cii.). This is based on the experience of one-sixth of the whole population of England and Wales (4,606,503 persons), which had death-rates in a standard population below 15 per 1000 in 1881–90.

The death-rate among infants under one year, as shown by this life-table, is even under the most favourable circumstances very high; an equally high death-rate not being again experienced until the age of about 80 years. About half of the first year's mortality occurs in the first three months.

EXPERIENCE OF 1881–90.
NUMBER OF SURVIVORS AT EACH AGE OUT OF 1000 LIVE-BORN.

	Males.		
	England and Wales.	Manchester Township.	Selected Healthy Districts.
Born	1000	1000	1000
3 months	921	895	936
6 do.	889	846	914
12 do.	839	769	881
	Females.		
Born	1000	1000	1000
3 months	938	918	951
6 do.	911	975	934
12 do.	869	808	907

It is evident that the gain from being born in a healthy district is even greater in the latter nine than in the first three months of the first year of life, thus strongly confirming the figures given in the preceding paragraph from three selected counties and towns.

Causes of Death among Infants. In the following table the deaths of male and female infants under one year of age in England in the year 1895, are arranged in the order of the number of deaths from each cause. It will be observed that the deaths are also stated for each sex in proportion to the infantile population; *i.e.*, the nearest approximation to it that is ascertainable, viz., the number of births during the year; and in proportion to the deaths from the same disease at all ages. The percentages under the last heading give useful information as to the relative proportion of deaths from different causes occurring under one year of age; but they cannot be trusted beyond this. Thus a serious error would be caused by arguing that because 12·2 and 25·1 per cent. of the total fatal accidents at all ages in the male and female sex respectively occurred under one year of age, female infants were more subject to accident than male infants, the difference being caused by the fact that at higher ages females are much less subject to fatal accident than males. The real facts are in favour of female infants, only 2·9 out of every 1000 born dying under one year as the result of accident, while 3·1 die among male infants.

The largest producer of infantile mortality (atrophy, debility and inanition) evidently includes a large number of ill-defined conditions, many of which are congenital. Diarrhœa will be considered later (p. 204). Convulsions again include diverse conditions, of which some at least are connected with parturition. This is indicated by the higher mortality from this cause among male infants, and by the fact that over 50 per cent. of the infantile deaths from convulsions occur under three months of age. It is remarkable that under so many heads there is an excess of male over female mortality. The only heading among the fifteen chief causes of infantile mortality tabulated on p. 125, under which female infantile mortality is higher than male, is whooping-cough (see opposite page).

Accompanying the life-table in the *Fifty-fourth Report of the Registrar-General* is a discussion of the facts relating to the chief causes of infantile mortality in England and Wales, 1889–91.

In this report the causes of death of infants who die in the first year of life out of 100,000 live-born children are examined. The following features are seen to hold for both rural and urban experience. The excessive mortality of the first month is almost entirely due to premature birth, congenital malformations, and feeble vitality (atelectasis, atrophy, convulsions). Over four-fifths of the deaths in the first month are returned under these five headings. Diarrhœal complaints reach their maximum destructiveness in the third to the sixth month. Dentition appears as a cause of death oftenest in the last three months of the year. The comparative immunity from zymotic diseases of infants in the earliest months is very marked. Whooping-cough appears earliest. The deaths from measles do not become numerous until the eighth

Deaths of Infants under One Year of Age, England and Wales, 1895.

Causes of Death.	No. of Deaths.		Deaths under 1 year per 1000 Births of		Deaths under 1 year per 1000 Deaths at all ages of	
	Males.	Females.	Males.	Females.	Males.	Females.
Debility, Atrophy, Inanition	11,755	9,173	25·1	20·3	93·3	91·7
Diarrhœa, Dysentery and Cholera	10,554	9,023	22·5	19·9	73·3	69·4
Convulsions	10,032	6,812	21·4	16·6	87·7	78·8
Premature Birth	9,856	7,649	21·0	16·9	100·0	100·0
Bronchitis	8,966	6,812	19·0	15·0	36·0	22·3
Pneumonia	5,187	3,680	11·1	8·1	25·6	24·1
Enteritis	3,649	2,979	7·8	6·6	64·8	59·6
Whooping-cough	2,119	2,297	4·5	5·1	49·6	43·2
Tabes Mesenterica	2,171	1,684	4·6	3·7	55·7	48·4
Atelectasis & Congenital Malformations	1,832	1,717	3·9	3·4	95·5	90·8
Accident and Negligence	1,474	1,315	3·1	2·9	12·2	25·1
Measles	1,414	1,154	3·0	2·5	24·1	20·5
Dentition	1,380	1,085	2·9	2·4	59·8	57·2
Inflammation of Brain and Membranes	1,361	1,052	2·9	2·3	33·9	29·7
Tubercular Meningitis	1,211	889	2·6	2·0	32·8	29·2
All remaining Causes	—	—	20·6	17·3	—	—
	82,655	65,438	176·2	144·3	28·4	23·5

or ninth month. Scarlet fever scarcely makes its appearance in the first year of life.

The mortality from diarrhœal complaints is more than seven times, that from measles and scarlet fever is more than three times, as great in the town as in the country. Syphilis shows itself still more as an urban disease. Suffocation, mostly from overlaying in bed, and generally due to drunkenness, is also greatly in excess in towns. The mortality from premature birth is nearly twice as high in the towns as in the rural counties.

Factors of Infantile Mortality. Some of the causes of infantile mortality are common to every locality. Such are—

(1) *Prematurity of birth* and *congenital defects.* The health conditions under which the mother lives have an undoubted

influence on the vitality of her progeny, and on the occurrence of premature birth.

(2) *Hereditary tendencies*, such as the inheritance of syphilis, or degradation and drunkenness of parents, have also a very important influence. Some check on the marriage of unsuitable people has been suggested, securing the greatest good of the greatest number, and, in Dr. Farr's words, rendering "growth more perfect, decay less rapid, life more vigorous, and death more remote." The practicability of this is, however, more than doubtful.

(3) The inexperience and *neglect of mothers*, especially of the industrial classes, is a most important factor in infantile mortality. As regards *inexperience*, it has been suggested that the deaths of first-born children should be separated from the general infantile mortality. Such returns would undoubtedly show that first-born children die at a higher rate than children of a later birth; but some of the excess would be attributable to greater difficulty in parturition, as well as to parental inexperience. Neglect on the part of parents is largely due to—

(4) *Industrial conditions*. In the large centres of industry the employment of women in mills during pregnancy and at an early interval after childbirth has a deleterious effect on the welfare of their infants. The latter are sent out to nurse during the day, and commonly fed on farinaceous food, instead of milk.

The following table suggests a partial but not a regular relationship between under-age marriages of women and a high infantile mortality.

Locality.	In 1895.	
	Out of 1000 marriages the number occurring under 21 among women was	The number of deaths of children under one year to 1000 births was
Staffordshire	212	176
Nottinghamshire	237	167
Derbyshire	227	149
West Riding } Yorkshire	203	174
East Riding } Yorkshire	208	187
Durham	244	181
Northumberland	200	166
Monmouthshire	245	149
England and Wales	174	161

Dr. Geo. Reid, in a paper read before the British Medical Association, 1892, gave the following statistics of infantile mortality in relation to the employment of married women in factories in Staffordshire. The population included in the statistics amounted to 438,712, and the statistics covered a period of ten years. Only towns having distinctly artisan populations were included. The towns were then classified under three heads as shown below:—

STAFFORDSHIRE.

	Average Rates in Groups of Towns for 10 years, 1881-90.			
	Mean Population.	Deaths of Children per 1000 Births.	Deaths from Diarrhœa per 1000 Births.	General Death-rate per 1000 of Population.
Class I. Many women engaged in work .	112,078	195	28	22·8
Class II. Fewer women engaged in work .	161,560	166	20	19·4
Class III. Practically no women engaged in work . . .	165,074	152	19	18·1

Although it is probable that other factors were co-operating, the preceding figures seem to betoken a relationship between the factory employment of mothers and an excessive death-rate among their infants. There are, however, certain facts which appear to indicate that female occupation is not the chief factor at work. Thus in the mining districts of Durham and South Wales, in which women are not much engaged in industrial occupations, the infant mortality is higher than in the West Riding of Yorkshire, where many married women are employed in factories. Similarly the gradual increase in the number of premature births has been ascribed to the increasing industrial employment of women; but the death-rate from premature births is higher in Norfolk and Suffolk, where only 20 per cent. of the women are engaged in some occupation, than in Lancashire and the West Riding of Yorkshire, where as high a proportion as 37 to 43 per cent. of the women are thus employed (N. A. Humphreys).

(5) *Social position* is closely related to industrial conditions in its influence on infantile mortality. Thus in 1897 the infantile mortality per 1000 births ranged in London from 116 in Plum-

stead and 127 in Hampstead to 195 in St. Saviour's, and 197 in St. George's-in-the-East; in the thirty-three great towns it ranged from 131 in Huddersfield to 262 in Preston; and in sixty-seven other large towns it ranged from 102 in Hornsey to 254 in Longton. Here we evidently have intermingled the effects on infantile vitality of social, industrial, and sanitary conditions of life. *Farr's Healthy Districts Life-Table*, based on the experience of sixty-three rural districts, showed an infantile death-rate of 103. Mr. C. Ansell (*Statistics of Families in Upper and Professional Classes*, 1874) found as the result of an inquiry relating to 49,099 English children of the upper and professional classes, of whom 2 per cent. were still-born, an infantile mortality of 80·5 per 1000 born.

(6) *Improper food* and methods of feeding are responsible for a large share of infantile mortality. The improper substitution of farinaceous for milk food has been already mentioned. The use of uncleanly bottles containing milk in an incipient state of putrefaction is a common source of infantile diarrhœa. The close connection between methods of feeding and infantile mortality is shown by the fact that during the sufferings and starvation connected with the siege of Paris in 1870–71, while the general mortality was doubled, that of infants is said to have been reduced by about 40 per cent., owing to mothers being obliged to suckle their infants. The same increase of adult and diminution of infant mortality was seen during the Lancashire cotton famine, when mothers were not at work at the mills. When improper feeding is a chief factor in producing infantile mortality, then a large proportion of the deaths are from diarrhœa and digestive diseases. Convulsions, again, are very commonly due to the irritation produced by improper food.

(7) The deaths from accidental or homicidal *violence* require consideration.

In 1895, 29·6 per cent. of the total homicides in England and Wales (311), and 15·9 per cent. of the total accidental deaths (17,543) occurred among infants under one year of age. The infantile death-rate from accident and negligence was in the same year for males 3·1 per 1000 births, for females 2·9 per 1000 births. The number of deaths of infants from suffocation in bed has increased from 124 per 1,000,000 births in 1885 to 174 in 1890. Dr. Ogle found that these deaths occur chiefly on Saturday nights, the night on which there is the maximum amount of drunkenness.

Influence of Age of Parents on Vitality of their Children. Dr. Matthews Duncan showed that the vitality of infants in a maternity hospital was greatest when the age of the mother was about 24 years. Körösi has investigated the same subject (*Transactions of the International Congress of Hygiene and Demography*, London, 1891, vol. x. p. 262) from the records at Budapesth of the death of 29,813 children under ten years of age in relation to the age of their parents. Körösi classifies the cause of death in these children as "uterine," as premature birth, weak constitution, and "extrauterine," where the cause of death is acquired after birth. Diarrhœa is taken as the most important instance of the latter. The general result is, that with the youngest mothers the number of weakly children is greatest.

The influence of the mother is shown in the following table:—

Age of Mother.	Out of 100 Deaths the cause of Death was	
	Weakness or other Uterine Cause.	Diarrhœa.
Under 20 . .	57·5 %	26·3 %
20–30 . . .	36·0 %	21·9 %
30–35 . . .	26·9 %	18·1 %
Above 35 . .	28·8 %	19·3 %
	If the mortality 20–30 be stated as 100, the following table is obtained:	
Under 20 . .	158	120
20–30 . . .	100	100
30–35 . . .	77	82
Above 35 . .	82	88

On the father's side the youngest parents also appear to disadvantage. Körösi gives elaborate statistics bearing on the influence of the difference of age and the combined ages of the two parents. The general lessons confirm those taught by other considerations, viz., that girls should not marry before the age of 20, and that old men ought not to marry young women. The inquiry is interesting, and it is unfortunate that the defective natal statistics in this country do not permit of its pursuit. It is particularly important that such statistics should be so classified as not to introduce the disturbing influence of social position.

Infantile Mortality in different Countries. The following table from Bertillon (*op. cit.*, p. 83) gives important data for different European countries:—

Country.	Period of Observation.	The number out of every 1000 live-births	
		Dying under one year of age.	Dying (0-5) under five years of age.
Ireland	1865–83	95 9	164·6
Norway	1866–82	104·9	179·1
Scotland	1865–81	122·0	230 9
Sweden	1866–82	131·9	222·5
Denmark	1870–82	137·5	204·9
Belgium	1867–83	148·2	253·2
England and Wales	1866–82	149·2	249·3
Finland	1878–80	164·9	—
France	1875–82	166·2	251·1
Switzerland	1869–80	195·2	266·3
Prussia	1874–82	207·8	316·2
Italy	1872–82	209·7	378·5
Austria	1866–83	255·3	389·9
Russia in Europe	1867–78	266·8	422·9
Bavaria	1866–83	308·4	393·2

In Massachusetts in the twenty years 1874–93, the infant mortality per 1000 births ranged between 172·0 (in 1875) and 152·4 (in 1877), the mean being 161·9.

In Hamburg, the mortality under one year old in the years 1882–96 per 1000 living at this age, has ranged from 201·9 in 1894, to 368·8 in 1886. Reference must be made to p. 80 for a caution as to the use of the above figures, owing to the varying significance of the term *still-born* in different countries. In England during 1891–95, the number of deaths under 5 years of age per 1000 births was 228·9, while the infantile mortality was 151 per 1000 births.

Effect of Illegitimacy on Infantile Mortality. An examination of Table 11, *Registrar-General's Annual Report*, 1896, p. lii., does not show any constant relation between the rate of illegitimacy and the entire infantile mortality in the different English counties. Possibly a certain number of illegitimate births are in towns registered as legitimate, while in rural districts they are correctly registered; a few illegitimate children again escape registration altogether. If, however, we separate the births of legitimate and illegitimate children, and adopt a like method for the corresponding deaths, the real facts are brought to light. The following figures for Brighton illustrate this point:—

	1892.	1893.	1894.	1895.	1896.	1897.
Deaths of legitimate infants per 1000 legitimate births	134	158	135	151	129	135
Deaths of illegitimate infants per 1000 illegitimate births	360	319	173	358	233	265

Thus an illegitimate child born in Brighton during 1897 had less than one-half the prospect of reaching the end of its first year of life which was enjoyed by a child born in wedlock.

Dr. Farr summarized a large number of returns on the same subject as follows:—

	Number of deaths of legitimate infants per 1000 legitimate births.	Number of deaths of illegitimate infants per 1000 illegitimate births.
Twelve districts with a low infantile mortality . .	97	388
Twelve districts with a high infantile mortality . .	192	366

In the face of such facts, the importance of illegitimacy as a national calamity is evident, and the following remarks, quoted by Dr. Farr from Von Bernoulli, are so apposite that we reproduce them here: "The invariable fact that the mortality among the illegitimate is far greater than among the legitimate, and that many more of them are still-born, shows clearly enough how much more unfavourable their position is from the first. Who can doubt that their bringing up is much harder and more difficult? that the existence of a class of men, bound to society by few or no family ties, is not a matter of indifference to the State? The great majority of foundlings are illegitimate, which of itself shows how little, as a general rule, the mothers can or will care for these children. It is beyond doubt that fewer illegitimate children grow up to maturity—that they get through the world with more trouble—than children born in wedlock, that more of them are poor, and that therefore more of them become criminals. Illegitimacy is in itself an evil to a man; and the State should seek to diminish the number of these births, and carefully inquire to what circumstances any increase is to be ascribed."

The necessity for regulations respecting illegitimate infants is indicated by the significant fact that, according to Dr. Lankester's evidence in 1871, the inquests requiring to be held on illegitimate children under one year of age amounted to 31 per cent. of all the inquests held on infants, although such children formed less than 5 per cent. of the total number of births.

Such facts as the preceding led to the passing of the Infant Life Protection Act, 1892.

This Act enacts that any person receiving for hire or reward more than one infant under the age of 5 years for the purpose of nursing such infants for a longer period than 48 hours, shall give immediate notice to the Local Authority, stating particulars as to age, sex, name, &c., of the children. Notice must also be given of the removal of such children. It is the duty of every Local Authority to provide for the execution of this Act within its district, and for that purpose may appoint inspectors to enforce the Act, for whom power of entry is given. It is the duty of the Local Authority to fix the number of infants under the age of 5 years who may be kept in any dwelling under this Act.

Any person keeping an infant under the age of 2 years, on consideration of a sum of money not exceeding £20 paid down, and without any agreement for further payment, shall give notice to this effect to the Local Authority.

It is the duty of the Local Authority to give public notice of the provisions of this Act.

When any infant coming within the terms of this Act is kept in any house so unfit or so overcrowded as to endanger its health, or is retained by any person who by reason of negligence, ignorance, or other cause is so unfit to have its care as to endanger its health, any person appointed for the purposes of this Act may apply to the Local Authority for an order directing him to remove the infant to a workhouse or place of safety.

An inquest must be held in case of the death of any infant respecting whom notice is required under this Act.

Insurance of Infants in Relation to Infantile Mortality. Much evidence has been published on this subject, which has both statistical and social interest. In England, in 1890, there were 4,150,000 children under 10 years of age insured, such insurance, especially for infants, being general among the industrial classes. The maximum sum which is legally payable on the death of a child under 5 years is £5; the maximum sum in the case of a child under 10 years is £10. The matter has been frequently revised from the legislative standpoint. The Friendly Societies Act of 1829 allowed minors to become members. The

Act of 1846 limited the insurance to those over 6 years of age. After an investigation by a Committee of the House of Commons, in 1849, the Act of 1846 was altered in 1850, it being rendered lawful to assure on the death of a child under the age of 10 years to the extent of actual funeral expenses, payment of which must be made to the undertaker direct. In 1854 the amount that could be paid on a child's death was again enlarged. In 1875, after further investigation, the Act was still further broadened, so as to allow of the insurance on children under 10 years of age being paid to the parents. A more recent Parliamentary inquiry reported, in 1891, that they did not consider further legislation necessary.

The Prudential Assurance Company have a table based on the experience of nine million insured lives, with which they contrast the experience of Farr's English Life-Table. The relative infantile mortality in the two is 99·5 and 165·5. As the insurance experience almost certainly does not include many new-born infants, it is proposed to omit the first month's deaths from the English figures. When this is done, they become 108, as against the Prudential 99·5. At ages one to two the respective death-rates, according to English and the Prudential Society's experience, are 65·6 and 63·2; two to three, 36·1 and 32·4; three to four, 24·3 and 18·6; four to five, 17·9 and 13·5; five to six, 13·5 and 10·0; six to seven, 10·7 and 7·6; seven to eight, 9·16 and 5·7; eight to nine, 7·7 and 4·9; nine to ten, 6·6 and 4·3.

There are other similar statistics, and it appears fairly clear that after free allowance for selection of insured lives, and for the fallacies connected with the extremely high mortality soon after birth, there is no trustworthy statistical evidence of the ill effect on the life-prospects of children from life insurance. There is no proof that neglect and crime have been greater in their incidence upon insured children, and it can scarcely be held that the prospective receipt of insurance money has been the incentive to child neglect and child murder in more than a very small number of cases.

Relation between Birth-rate and Infantile Mortality. The infantile deaths being stated in their ratio to the infantile population, or the nearest approximation to it—in the number of births—that can be ascertained, it is evident that the number of deaths under one year will necessarily increase with the number of births. There is, however, nothing in this to imply that the infantile *death-rate* should be increased by a higher birth-rate. Dr. H. R. Jones (*Jour. Statist. Soc.*, vol. lvii. part i.) has found a local connection in northern towns between a high birth-rate and a high infantile death-rate, as shown in the following table:—

NORTHERN TOWNS, 1871–80.

Birth-rate.	Rate of Infantile Mortality.
Over 35	168
Under 35	144

The association is by no means regular, nor do we consider it inevitable. If the birth-rates and the infantile death-rates in the thirty-three great towns in 1897 be analyzed, the ten towns with the highest birth-rates are Gateshead, 35·1; Liverpool, 35·3; Wolverhampton and Salford, 35·1; Sunderland, 34·6; Sheffield, 34·4; Hull, 33·4; Birmingham, 33·3; Manchester, 33·2; and West Ham, 32·2. The ten towns with the highest infantile death-rates were Preston, 262; Burnley, 220; Salford, 219; Wolverhampton, 217; Birmingham, 214; Nottingham and Blackburn, 206; Leicester, 205; Liverpool, 200; Sheffield, 198. Thus five appearing in the last list do not appear in the first.

There is nothing surprising in the frequent association of a high birth-rate and a high rate of infantile mortality. The highest birth-rates usually occur in crowded industrial towns, in which the evil effects of industrial occupation of married women are commonly associated with those of intemperance, ignorance, and neglect, with all that these factors imply.

A high degree of **density of population** is not necessarily associated with a heavy infantile death-rate. Thus I have shown (*Jour. Statist. Soc.*, March, 1891) that in the Peabody Buildings having an average density of 751 persons to an acre, as compared with 58 persons to an acre in the whole of London, there was infantile mortality averaging 139 in the nine years 1882–90, as compared with 152 for the whole of London. Increased density of population, however, commonly carries with it other evils. "The direct consequences of close aggregation" (liability to fouling of the air, the soil, and often the water, and the more easy spread of infectious diseases) "are probably as nothing in comparison with its indirect consequences or concomitants. The more crowded a community, the greater, speaking generally, is the amount of abject want, of filth, of crime, of drunkenness, and of other excesses, the more keen is the competition, and the more feverish and exhausting the conditions of life. Moreover, and perhaps more than all, it is in these crowded communities that almost all the most dangerous and unhealthy industries are carried on. It is not so much the aggregation itself as these other factors which are associated with aggregation, that produce the high mortality of our great towns or other thickly populated areas." (*Supplement to Forty-fifth Annual Report of the Registrar-General*, p. xxi.) The effect of unhealthy industries is only felt indirectly by the infantile population; but, apart from this, the above remarks explain clearly why great density of population and the high birth-rate commonly accompanying it are usually associated with a high rate of infantile mortality.

The following remarks from my paper on "The Vital Statistics of Peabody Buildings," appear to me to state the true relationship between a high death-rate, especially a high infantile death-rate, and density of population.

"The number of rooms occupied by each family is of much greater importance in relation to health than the number of persons living on a given acre, as this fact throws important light on the state of each tenement as regards overcrowding. In the Peabody Buildings the average number of persons to each room is 1·8. Given houses properly constructed and drained, and given cleanly habits on the part of the tenants, increased aggregation of population on a given area has no influence in raising the death-rate, except in so far as it is accompanied by *overcrowding in individual rooms*, an event which is by no means necessary under the circumstances named. In other words, there is no causal relationship between density of population *per se* and a high mortality. The true index of density is the number of persons to each occupied room."

CHAPTER XV. Y

INFLUENCE OF CLIMATIC AND SOCIAL CONDITIONS ON MORTALITY.

WE have in the last two chapters discussed the effect of varying age and sex-distribution on the general death-rate, and on the death-rate at different age-groups. Before considering the mortality from special diseases, the influence of climatic and social conditions, of density of population, and occupation, require attention, and to these the present and two subsequent chapters will be devoted.

The influence of climate can only be separated with difficulty from that of other conditions of environment. To obtain trustworthy statistics under this head, it would be necessary to eliminate the effect of variations in the age-distribution of the populations compared, of density of population, staple industries, and of differences in food and in other particulars. The Army Reports for different foreign and home stations are a most promising field of investigation in this connection, if the necessary precautions above indicated are taken. It is well in investigations concerning climate to consider separately its effect on strangers and on the indigenous inhabitants.

Many important facts as to the connection between climate and disease can be statistically elucidated, as the varying amount of malaria, the endemic and epidemic prevalence of cholera, the localized distribution of yellow fever and leprosy, the almost complete absence of diphtheria from tropical regions,* and so on.

Season has an influence which can easily be stated in figures. It is customary to separate the death-rates from all causes and from different diseases according to the quarter of the year.

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* See *Epidemic Diphtheria*, by the Author, p. 152.

Another plan, presenting some advantages, is to divide the number of cases of, or deaths from, a disease into those occurring in the winter—December to February, in the spring, March to May, in the summer, June to August, and in the autumn, September to November. It is often useful also to state the number of cases or deaths for each month of the year. When this is done the object, presumably, is to give the relative incidence of the disease in each month, and for this purpose a correction is required for the varying lengths of the months. The following example is taken from Dr. Abbott's report (*Twenty-sixth Annual Report, State Board of Health, Massachusetts*).

MORTALITY BY MONTHS, MASSACHUSETTS, 1893.

	Total Deaths in Month.	Monthly Deaths reduced to a Standard of 100.	Deaths per day.
January . . .	4161	99·8	134·2
February . . .	3714	98·6	132·6
March	4375	104·9	141·1
April	4335	107·4	144·5
May	4321	103·6	139·4
June	3250	80·5	108·3
July	4356	104·5	140·5
August	4934	118·4	159·2
September . . .	4055	100·5	135 2
October . . .	3679	88·3	118·7
November . . .	3480	86·3	116·0
December . . .	4424	106·1	142·7
	49084	100	134·5

The standard month is assumed to contain 31 days. The average number of deaths in 31 days $= \dfrac{49084 \times 31}{365} = 4169.$

But in January 4161 deaths occurred in 31 days.

Therefore the deaths in this month were $\dfrac{4161 \times 100}{4169} = 99{\cdot}8$ per cent of the standard.

Similarly for February, first find what would have been the number of deaths had this month had 31 days in it.

$$\frac{3714 \times 31}{28} = 4112.$$

Then the deaths in the second month of 31 days were

$$\frac{4112 \times 100}{4169} = 98{\cdot}6 \text{ per cent of the standard.}$$

And so on for the other months.

From 1886 to 1896 inclusive, the death-rate in England has always been highest in the first quarter of the year, with the exception of 1891, in which it was higher in the second quarter (23·7 as compared with 22·0), 1893, in which it was higher in the fourth quarter (19·9 as compared with 19·7), and 1896, in which the death-rate in both the first and fourth quarters of the year was 17·9. The third quarter usually has the lowest death-rate. In 1886–96 it was lowest in this quarter, except in 1893, when it was lower in the second quarter (18·0 as compared with 19·2); in 1895, when it was also lower in the second quarter (17·2 as compared with 17·5); and in 1896, in which both the death-rates in the second and third quarters was 16·3. In the years 1838–95 the English death-rate for the first quarter averaged 23·8, for the second 21·0, for the third 19·5, and for the fourth 21·0 per 1000 per annum. The low mortality in the third quarter of the year would be still more marked but for the prevalence of Epidemic Diarrhœa.

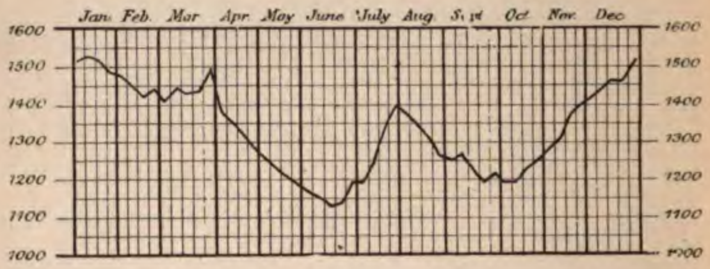


FIG. 9.

Seasonal Incidence of Deaths from all causes in London (50 years, 1841–90).

Mild winters and cool summers both lower the mortality, the former especially of the old, the latter of the young, and especially of the infantile population. A cold, wet summer is always accompanied by a low mortality. The effect of an excessively cold winter and of a cool summer on the weekly

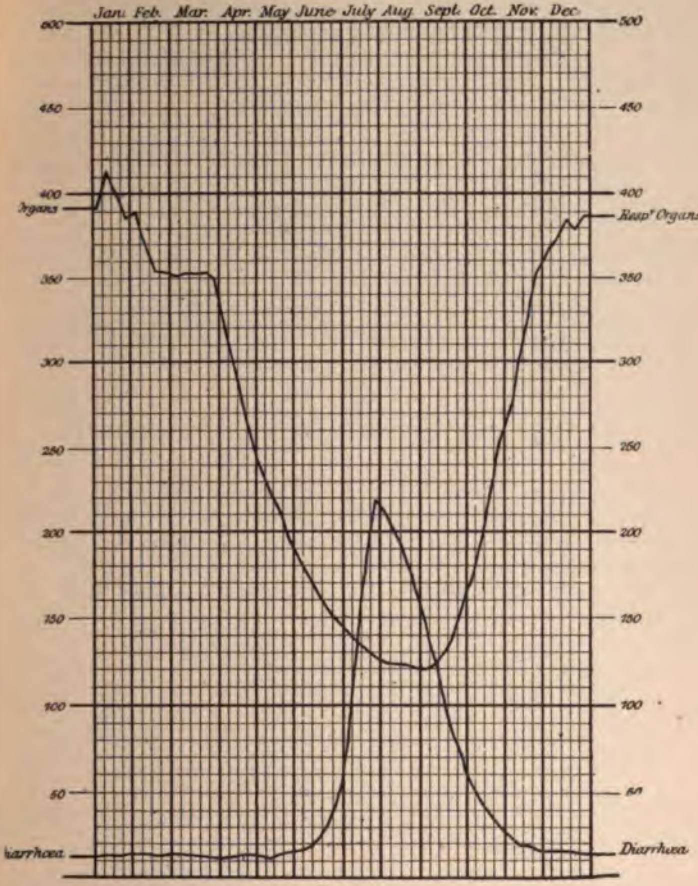
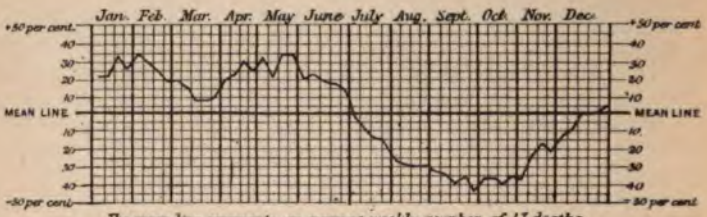


FIG. 10.

Seasonal Incidence of Deaths from Diseases of the Respiratory Organs and from Diarrhœa in London (50 years, 1841–90).

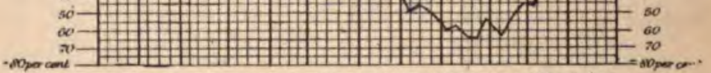
mortality in London at all ages, at ages over 60, and under one year of age respectively, may be seen by plotting out the deaths under these three heads diagrammatically. The figures for this purpose can be obtained from the weekly returns of the Registrar-General. If the period 1890-91 be taken, the returns show the effect of the intrusion of an additional cause of mortality—influenza—April to June. The diagram may be commenced with the week ending November 8th, 1890, in order to illustrate the effect on total deaths and deaths over 60 of the exceptionally excessive cold which occurred between November 25th and January 22nd. Between November 25th and December 31st the average deficiency of the mean daily temperature was 11°·4 Fahr., being as much as 21°·4 below the average on November 28th, and 21°·0 below on December 22nd. In the first 22 days of January



The mean line represents an average weekly number of 17 deaths

FIG. 11.

Seasonal Incidence of Deaths from Small-pox (50 years, 1841-90).

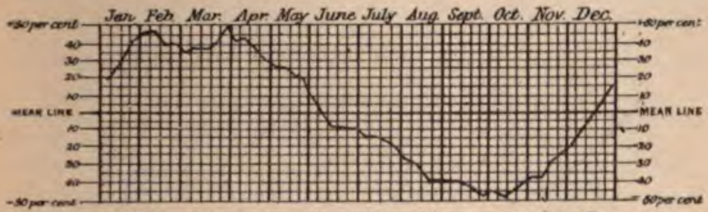


The mean line represents an average weekly number of 57 admissions

FIG. 12.

Seasonal Incidence of Admissions of Small-pox Patients to Metropolitan Hospitals (15 years, 1876-80).

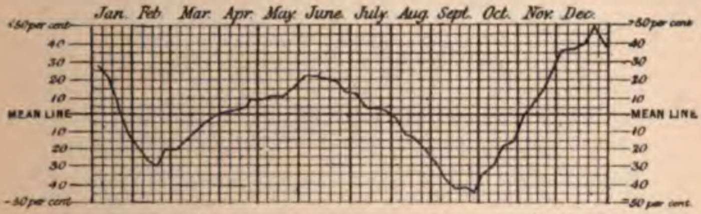
the mean daily deficiency of temperature from the average was 7°·9, the greatest deficiency being 18°·7 on the 10th. The effect of this protracted and exceptional cold is seen in the curve of total deaths, and particularly in that of persons over 60, very slightly in the curve of deaths of infants. In April a new cause of excessive mortality, viz., influenza, intruded itself. The official figures do not sufficiently show the true share of influenza in this excessive mortality, as deaths from bronchitis and pneumonia were also very excessive, and had a common origin in influenza. The rise in mortality in August was unusually small in extent. It was almost entirely confined to infantile life, and was caused by diarrhœa. The explanation of the small amount of diarrhœa in the summer of 1891 lies in the fact that



The mean line represents an average weekly number of 47 deaths

FIG. 13.

Seasonal Incidence of Deaths from Whooping-cough in London (50 years, 1841–90).



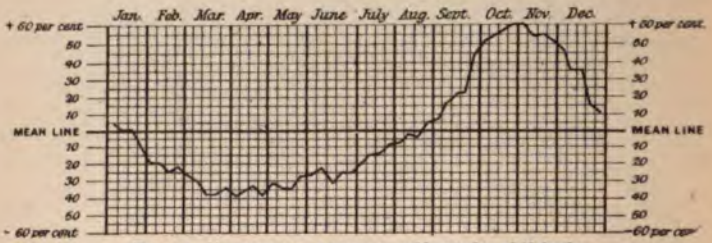
The mean line represents an average weekly number of 34 deaths

FIG. 14.

Seasonal Incidence of Deaths from Measles in London (50 years, 1841–99).

the mean temperature was below the average from July 1st to September 7th, on August 6th as much as 9°·5 below.

Season has, it will be seen, an important influence on the character of prevalent diseases, intestinal diseases being most prevalent in summer, and respiratory diseases in winter.

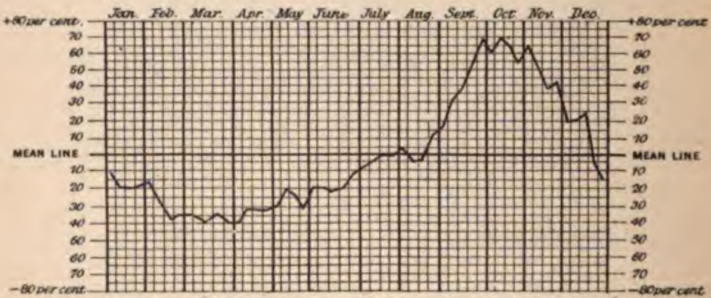


The mean line represents an average weekly number of 44 deaths.

FIG. 15.

Seasonal Incidence of Deaths from Scarlet Fever in London (30 years, 1861–90).

The following curves, taken from the *Annual Summary of the Registrar-General*, 1890, illustrate very clearly the seasonal incidence of general mortality and of the mortality and prevalence of certain diseases.

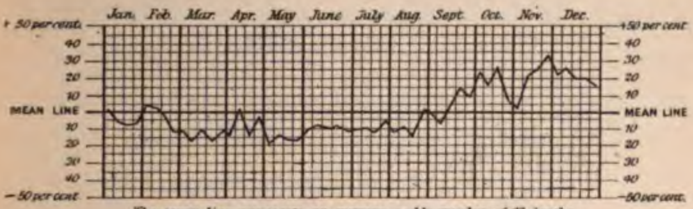


The mean line represents an average weekly number of 55 admissions.

FIG. 16.

Seasonal Incidence of Admissions of Scarlet Fever Patients to Metropolitan Fever Hospitals (16 years, 1875–90).

Figs. 9 and 10, relating to "Deaths from all Causes" and "Deaths from Diseases of the Respiratory Organs" and from "Diarrhœa," show the actual average deaths each week. In these diagrams the thick horizontal line represents the weekly mortality from the disease to which the diagram relates, the fifty-third week, when it occurs, being ignored. The curved line represents the amount per cent. by which the average mortality in each week differs from this mean, above or below it. The length of experience taken as the basis is stated in each instance; usually it is 50 years. Some allowance must be made for the facts that the curves are formed on the deaths registered in each week, registration usually occurring a few days after death, and that the curves relate to deaths, the end of each fatal attack, not the date of attack. Furthermore, the fatality (case-mortality) of certain diseases varies according to season. For this reason curves of weekly admissions of any of the diseases which are treated on a large scale in public hospitals are also given. Allowance must be made in the curves of weekly admissions for the fact that, unless a long series of years is taken, the chance fluctuation caused by an unusually large epidemic occurring possibly at an unusual season disturbs the symmetry of the curve. The following remarks in the *Annual Summary of the Registrar-General*, 1890, so clearly bring out the chief points of interest in the different curves, that they are reproduced:—

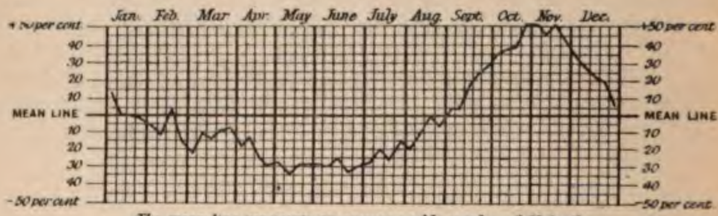


The mean line represents an average weekly number of 73 deaths

FIG. 17.

Seasonal Incidence of Deaths from Diphtheria in London
(30 years, 1861–90).

"It is of interest to compare the admission curves (Figs. 12, 16, 19) with the corresponding mortality curves (Figs. 11, 15, 18). We should anticipate that, as the former relate to the commencements of the attacks and the latter to their terminations when fatal, the maximum and minimum points in the former would precede the maximum and minimum points in the latter; and to a certain extent, though not quite so decidedly as might be expected, this is the case. We should also expect that the seasonal differences in the admission curves would be more strongly marked than in the death curves; for the deaths that occur among the attacks of a given week will not all occur in one other later week, but will occur gradually and be spread over several successive weeks; so that while the number of attacks in a given week will be represented by a single point, the deaths corresponding to those attacks will be represented by a more or less extended line, uniting successive points in several weeks, the number of which will depend upon the duration of the disease. The death curves, in short, should be flattened out in comparison with the admission curves, and the flattening should be greater the longer the usual duration of the disease. An examination of the curves shows that this anticipation is fulfilled. The three mortality curves are all more or less flattened as compared with the admission curves; and the flattening is greatest in the enteric fever curve, the average duration of this disease being the longest, and is least in the scarlet fever curve, in which disease the average duration is the shortest.



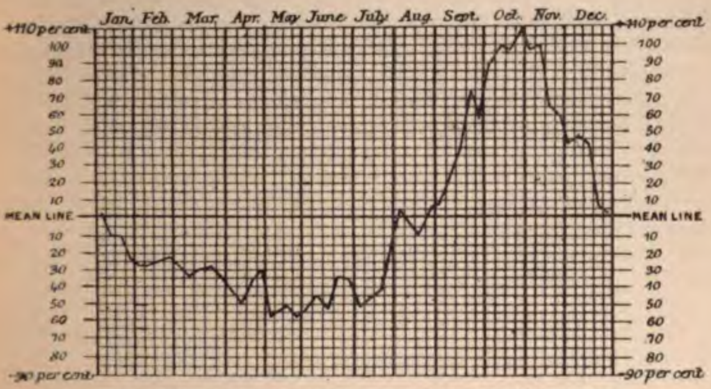
The mean line represents an average weekly number of 16 deaths

FIG. 18.

Seasonal Incidence of Deaths from Enteric Fever in London (22 years, 1869–90).

"This comparison gives us a notion of the changes that we must make in the mortality curves of the other diseases, in order to make them more closely represent the curves of seasonal prevalence. We must push the curves somewhat further back, so as to make maximum and minimum come respectively at a somewhat earlier date; and we must raise this maximum and lower this minimum to an extent determined by the number of weeks through which fatal attacks of the disease with whose curves we are dealing may extend.

"The curves tell their own story sufficiently distinctly to make it unnecessary to describe them severally in detail. They may, however, for convenience be classed in groups, according as the curve consists of a single or a double annual wave, and according to the periods of the year in which the wave or waves reach their highest and lowest points. The curves for diarrhœa and for diseases of the respiratory organs (Fig. 10) are distinctly single waves, the former with its crest in the summer, the latter in the winter; and it is the combination of these two very marked seasonal curves that mainly determines the double wave outline of the curve (Fig. 9) of mortality from all causes. The curves for scarlet fever (Figs. 15 and 16), diphtheria (Fig. 17), and enteric fever (Figs. 18 and 19), are also single wave curves,



The mean line represents an average weekly number of 9 admissions

FIG. 19.

Seasonal Incidence of Admissions of Enteric Fever Patients to Metropolitan Fever Hospitals (16 years, 1875–90).

closely resembling each other, in that in each of them the wave rises to its crest in October and November, while the trough extends from February to August. In strong contrast with this group are the curves of small-pox (Figs. 11 and 12), and of whooping-cough (Fig. 13), which cover with their crests January to June, while their troughs extend over the rest of the year. These curves, moreover, show some tendency to consist of two waves, for in each there is a slight but, nevertheless, distinct depression in the months of February and March. There remains the curve of measles (Fig. 14), which consists unmistakably of two waves, having their crests respectively in June and in December, while they fall to their lowest levels in February and September.

"The effects of small-pox and whooping-cough upon the general seasonal mortality are practically effaced by the almost exactly contrary effects of scarlet fever, diphtheria, and enteric fever; and thus the general outline of the curve of mortality from all causes (Fig. ~~19~~ 9) is mainly determined, so far as the diseases now considered affect it, by a combination of the curves for diseases of the respiratory organs, for diarrhœa, and, in a lesser degree, for measles."

Cyclical Changes. The fact that certain diseases, especially those of an infectious character, recur after an interval of years, shows that, apart from the influence of the season of year, there are periods of change which require for their completion a series of years. Mr. Netten Radcliffe has drawn attention to the fact that the law of periodicity of epidemic and pandemic diseases is not yet determined. Two factors appear to be at work: (1) the influence of an accumulation of susceptible persons in the intervals between two epidemics of the same disease; and (2) certain extraneous conditions which appear to be operative in determining the periodicity, but about which little is known. The first factor is exemplified by the fluctuations in the amount of small-pox in England, which have been observed to have a close relationship with the fluctuations in the number of unvaccinated children—a relationship so close that the periods of recurrence of epidemic small-pox could be pretty accurately forecasted. The second factor appears to be exemplified by the fact that, in 1871, when one of the periods of epidemic increase was due, some other undetermined condition gave to the epidemic of 1871–72 a severe character not observed in small-pox since the general introduction of vaccination. Mr. Radcliffe gives as other instances of a similar character the great epidemic of syphilis in the fifteenth century; the exceptional development of fatal diarrhœa in this century; the great development of diphtheria within the last thirty years; and the appearance within recent years of cerebro-spinal fever; which he regards as evidences of secular-pathological changes, to which a clue must be sought by studying their relation with secular meteorological and telluric changes. The solution of the problem why cholera is now endemic in India, then becomes epidemic, and finally pandemic at intervals, belongs to the same category.

Since the above was written rheumatic fever (Milroy Lectures, *Lancet*, March, 1893) and diphtheria (*Epidemic Diphtheria: a Research on the Origin and Spread of the Disease from an International Standpoint*, Swan Sonnenschein & Co., 1898) have been made the subject of a very detailed international study by the author. The result, particularly in the case of diphtheria, has been, it is believed, to elucidate the conditions determining the cycles of prevalence of the disease; and to prove that both diphtheria and rheumatic fever occur in epidemics almost exclusively under meteorological and telluric conditions which are very remote from those supposed by most medical men to be commonly associated with these diseases.

Effect of Race. The table on p. 16 shows the death-rate in different countries; it is obvious, however, that other causes of difference are at work in addition to race, and that correction is required for differences of age and sex-distribution.

Mr. Hoffman's treatise on *Race Traits and Tendencies of the American Negro* (1896, Publications of the American Economic Association) contains valuable statistics as to the vital differences between the white and coloured population in the States, based in part on the census report of 1890. Thus the combined experience of ten southern cities, 1890–94 (including Washington, Baltimore, and New Orleans) shows a death-rate among the white of 20·1, among the coloured population of 32·6, notwithstanding the fact that the age-distribution of the coloured is shown by the census returns to be far more favourable to a low general death-rate than that of the white population. These rates are based on populations of over 5 and 2 millions respectively. The following further death-rates may be quoted.

DEATH-RATES OF BALTIMORE AND WASHINGTON, D.C., FOR 1890, PER 1000 LIVING AT EACH AGE-GROUP.

Ages.	Baltimore, Md. White.	Baltimore, Md. Coloured.	Washington, D.C. White.	Washington, D.C. Coloured.
Under 5 years	80·3	171·8	65·0	159·3
,, 15 ,,	30·7	64·2	23·9	57·0
15–45 ,,	9·0	14·9	9·3	17·1
45 years and over	37·5	42·3	33·9	47·6

The percentage of excess of negro mortality is highest for the period of life under 15. Mr. Hoffman brings forward evidence to show that this is due more to race degeneration than to the fact that the environment of the coloured is worse than that of the white population. In the Northern States the coloured race does not hold its own, the deaths outnumbering the births; the apparent increase of the coloured population is due exclusively to migration. Mr. Hoffman shows also that the mortality in the coloured race is increasing, while that among whites is on the decline.

Medical experience in the war between the North and the South proved that the adult negro male was more subject to malarial disease than the white soldier, the rate of admissions to hospitals for malarial diseases being 522 per 1000 for the white troops, and 829 for the coloured troops; while the average death-rate in the two classes was 3·36 and 10·03 per 1000 respectively.

The excessive death-rate among negroes is caused chiefly by excessive infantile mortality, phthisis, pneumonia, scrofula, and venereal diseases.

In the year of the 1890 census, in American cities of 100,000 population and upwards, the following death-rates per 1000 of each population occurred, the deaths being classified *according to the birth-place of the mother*:

United States	20·87	Canada	19·61
England and Wales	19·38	Scandinavia	19·04
Ireland	26·74	Bohemia	27·19
Scotland	19·16	Italy	33·35
France	19·00	Other foreign countries	23·74
Germany	19·87		

Part I. of the *United States Eleventh Census Report* for 1891, "Vital Statistics," p. 38 *et seq.*, contains a number of further statistics bearing on race.

Effect of Marital Condition. The table on p. 62 shows at the time of the census 1891 that the proportion of unmarried in the English population diminished with each successive age-period. "As regards the earlier age-periods, this is readily intelligible, because marriage, as well as death, thins the ranks of the single until marriage-age is past." The persistent weeding out of the bachelors and spinsters, even in advanced life, can, however, so far as can be seen, be only explained by supposing that their rate of mortality is higher than that of married persons of similar ages. One would have anticipated that the weeding out of those who remain single, because unfit for matrimony, would have become complete before, say, the age of 55; and the fact that this is not so, lends itself to the view that married life is more favourable to longevity than celibacy.

The same conclusion is favoured by the results of the United States census, 1890, which should be consulted for particulars.

Effect of Sanitation. Between 1851 and 1871 the towns of England increased from 580 to 938, their population from nine to fourteen millions; but notwithstanding the tendency of greater density of population to be associated with an increased death-rate, the death-rate remained practically stationary. Since that time there has been a remarkable reduction in the death-rate, concerning which we cannot do better than quote the *Registrar-General's Report* for 1881 (p. xv. *et seq.*). "There is nothing in the series of annual reports issued by this office that comes out more distinctly and unmistakably than the wonderful effect which the sanitary operations of the last decade have had in saving life. The Public Health Act came into operation in 1872. The average annual death-rate for the immediately preceding ten years (1862–71) had been 22·6, and there were no indications whatsoever of any tendency of the rate to fall lower. Indeed, in 1871, the final year of this period, the rate was exactly the average, viz., 22·6. The Act came into force, and at once the rate began to fall, and continued to fall year by year with almost unbroken regularity, until in 1881 it was no more than 18·9. Once only in the ten years that had elapsed since the Act came into operation was the rate as high as the average of the previous decade. That was in 1875, when the rate was 22·7. In that year a second Public Health Act, of more stringent character, came into operation; and from that date down to 1881 the death-rate did not once reach 22·0, and averaged no more than 20·5.

"Had the fall in the death-rate been limited to a single year, or to two years, or even to three, it might have been argued by sceptical persons that the improvement was due to a succession of seasons favourable to health, or to other causes unconnected with sanitary administration, and that the setting in of the fall coincidently with the coming into operation of public health measures was no more than casual; but in face of a fall, lasting for ten years in succession, and increasing each year in amount, no one can seriously maintain such a position. There can be no real doubt that the saving effected in life was the direct product of the money and labour expended in sanitary improvements. Doubtless the money thus expended was enormous in amount; and it will be well, therefore, to consider what return it has brought in. If, then, the death-rate in 1881 had been only equal to the average death-rate in the decade preceding the Public Health Act of 1872, there would have died in the course of that one year 96,917 persons who, as it was, survived. From this total, however, a deduction must be made of some 5000 for the following reason:—The birth-rate in 1881 and in each of the two immediately preceding years was considerably below the average annual birth-rate in 1862–71. Consequently there was a smaller than average proportion of children in the first three years of life in the population of 1881. But the death-rate at this early period of life is always very high. Had the birth-rate in 1879, 1880, 1881, been equal to the average birth-rate in 1862–71, there would have been so many more young children living in 1881 as to have increased the deaths in that year by a number close upon 5000. Instead, therefore, of 96,917 lives saved, we have only about 92,000.

"Now we shall probably be well within the mark if we assume that for every fatal case of illness there are from four to five more cases which end in recovery. This is about the proportion in enteric fever, which is a more fatal disease than the average of diseases. The result, therefore, on this assumption would be that, speaking in round numbers, there were 500,000 fewer cases of illness, and 92,000 fewer deaths in England and Wales in 1881 than would have been the case had the population been living under the conditions that existed in 1862–71. It may, perhaps, be objected, and not unreasonably, that the year 1881, with its extraordinarily low death-rate, was so exceptional, that it can hardly be taken as a fair sample by which to measure the annual return in life and health from the moneys spent in sanitary improvements. Let us, then, take the entire period of ten years that elapsed between the first Public Health Act and the close of 1881. Had the death-rate remained during that period at its mean level in the preceding decade, the total deaths from 1872 to 1881 inclusively would have been 5,548,116, whereas they were actually no more than 5,155,367. Thus no less than 392,749 persons who, under the old *régime*, would have died, were, as a matter of fact, still living at the close of 1881. (The mean birth-rates in the two decades 1862–71 and 1872–81 were almost exactly the same, so that no correction need be made in this case.) Add to these saved lives the avoidance of at least four times as many attacks of non-fatal illness, and we have the total profits as yet received from our sanitary expenditure. Moreover, it is important to note that these profits were not equally spread over the ten years, but that there was a manifest tendency to progressive increase throughout the period. This is what might be anticipated; for the full effect of sanitary improvements requires time for development." The results just described, and their continuance and extension in more recent years, may be summarized as follows:—

	Period of Years.	Mean Annual Death-rate per 1000 living.
	Ten Years, 1862–71	22·6
Public Health Act, 1872—	Four Years, 1872–75	21·8
Public Health Act, 1875—	Five Years, 1876–80	20·79
	,, ,, 1881–85	19·30
	,, ,, 1886–90	18 89
	,, ,, 1891–95	18·74
	Year 1896	17·10
	,, 1897	17·40

The improvement shown above would have been even more striking but for the return of epidemic influenza, after an almost complete absence between 1858 and the end of 1889. Since December, 1889, this disease has caused a very large number of deaths, nor can it be said at present to be within the scope of active preventive measures. The extent of the decline in the death-rate at different ages and in the two sexes will be discussed later (p. 315).

Some allowance must be made for the more favourable age-constitution of the population in recent years, caused by the decline in the birth-rate from its highest point, 36·3, in 1876, to 29·7 in 1896. Comparing the mean populations for the decennia 1871–80 and 1881–90, it is found that the numbers of males and females living between the ages of 10 and 45 years were relatively greater in the later than in the earlier decennium. Thus the crude death-rate for 1871–80 was 21·27; that for 1881–90 was 19·08. Corrected for age-constitution, the former becomes 20·84, which should be compared with 19·08. (*Supplement to Fifty-fifth Report of the Registrar-General*, part i. p. viii.) It need hardly be said that a continuance of this declining birth-rate will eventually cause an age-distribution of population unfavourable to a low general death-rate. (See. p. 96.)

The same lesson as to saving of life is taught by the experience of the so-called Healthy Districts. In 1859 Farr published a *Life-Table of the Sixty-three Healthiest English Districts.* These were the districts which in 1841–50 had a crude death-rate below 17·5 per 1000. In 1841–50, less than 6 per cent. of the total population lived in districts which, "for the sake of convenience, were called healthy districts," and which had a crude death-rate below 17·5 per 1000. In 1881–90, on the other hand, 25 per cent. of the population lived in districts with a crude death-rate below 17·0 per 1000, and 4½ per cent. in districts with a crude death-rate not exceeding 15·0 per 1000. When allowances were made for differences of age and sex-constitution in the several districts, it was found that 263 districts, with a mean aggregate population of 4,606,503 persons, or about one-sixth of the whole population, had death-rates below 15 per 1000 in 1881–90. (*Supplement to Fifty-fifth Report of the Registrar-General*, part ii. p. ciii.) The new healthy district life-table given by Dr. Tatham is thus based on the experience of one-sixth of the population of the country.

CHAPTER XVI.

DENSITY OF POPULATION AND MORTALITY.

DR. FARR first called attention to the influence exerted by density of population on mortality in the *Fifth Report of the Registrar-General* (1843), and since that time statistics bearing on the question have regularly appeared in the Registrar-General's reports.

Method of Calculating Degree of Aggregation of Population. Two methods are commonly adopted. (1) The number of persons living to each square mile of area is stated. (2) The average number of acres occupied by each person in the population is stated.

The following table gives an example of both these methods:—

ENGLAND AND WALES—DENSITY AND MORTALITY.

	1851–60.	1861–70.	1871–80.	1881–90.
Death-rate per 1000 . .	22·2	22·5	21·4	19·1
Persons to a Square Mile .	325	365	416	470
Acres to a Person (mean density)	1·96	1·74	1·53	1·35

If Area = A, and population = P.

Then $\frac{P}{A} = D$ = mean population on each unit of area,

While $\frac{A}{P}$ = the mean area to each person.

The unit of space in the first method is taken to be a mile; in the second an acre.

Apparent densities of population do not always correspond with real densities, because the population in one of the towns to be compared may be lodged on only a portion of its area, the remaining area being occupied by a lake, common, park, etc. The usual plan adopted is to include these (thus diminishing the apparent density of population) if they are within the borders of the sanitary district.

Relation between Density and Mortality. Dr. Farr found that the mortality increases with the density of the population, but not in direct proportion to their densities, but as their 6th root.

Thus, if d and d' = density of population in two places,
and m and m' = mortality " " "

$$\text{then } \frac{m'}{m} = \sqrt[6]{\frac{d'}{d}}$$

$$\text{and } m' : m :: \sqrt[6]{d'} : \sqrt[6]{d}$$

In his report for 1843, Dr. Farr gives as examples seven groups of districts the death-rate of which, calculated from their densities, approximated very closely to the observed death-rates. Thus—

Death-rates—
Calculated: 18·90—19·16—20·87—25·92—28·08—37·70—38·74.
Observed: 16·75—19·16—21·88—24·90—28·08—32·49—38·62.

The formula was subsequently modified by Dr. Farr (*Supplement to Thirty-fifth Annual Report*, p. clviii.), 0·11998 being substituted for $\frac{1}{6}$ in the above formula; or, more exactly—

$$m' = m\left(\frac{d'}{d}\right)^{0{\cdot}11998}$$

Thus, in 1861–70, in the 345 districts which had a mortality of 19·2, the density was 186 persons to a square mile; in the 9 districts with a density of 4499, what was the mortality? It was happily not expressed by the proportion of the two densities; *i.e.*, $186 : 4499 :: 19{\cdot}2 : x$; but by this proportion nearly—

$$(186)^{0{\cdot}12} : (4499)^{0{\cdot}12} :: 19{\cdot}2 : x = 28{\cdot}1,$$

i.e., approximately as the 8th root of the density of the respective populations.

This formula only gives slightly different results from the preceding one. So closely was the ratio found to be followed in places whose sewage and water supply and other sanitary conditions were fairly the same, and which apparently differed only in density of population, that Dr. Farr went so far as to propose that in any sanitary inquiry the influence of density should first be discovered by means of the above formula, and that the effect of other influences above or below this should then be investigated. As he remarked, "the formula thus eliminates the element of density from the analysis of the causes of insalubrity."

If a constant relationship existed between the death-rate and density of population, an increased mortality might be expected with the course of events shown in the following table:—

ENGLAND AND WALES: DENSITY OF POPULATION.

Date of Census.	Persons per square mile.	Acres per person.	Proximity in yards.
1801 . . .	153	4·20	153
1811 . . .	174	3·67	143
1821 . . .	206	3·11	132
1831 . . .	238	2·69	123
1841 . . .	273	2·34	114
1851 . . .	307	2·08	108
1861 . . .	344	1·86	102
1871 . . .	390	1·64	96
1881 . . .	445	1·44	90
1891 . . .	497	1·29	85

But the table on p. 151 shows that the death-rate has steadily declined with increasing density of population. It is evident, therefore, that either the relationship between density of population and mortality is accidental rather than essential, or that important countervailing influences are at work.

Urban and Rural Mortality. There still remains a higher death-rate in urban than in rural districts, though the difference between the two is becoming gradually less. Between 1851–60 and 1896 the urban death-rate has declined 27 per cent. (from 22·2 to 17·1 per 1000), and the rural death-rate 23 per cent. (from 19·9 to 15·3 per 1000). This does not, however, represent the exact facts, as only crude death-rates have been used in the comparison. In the *Supplement to the Fifty-fifth Report of the*

Registrar-General, p. xlvii., is given a valuable table, reproduced below, in which groups of districts are classified according to density of population, and according to death-rates corrected for variations in age-constitution.

In the following table the above facts are given in the first three columns, and in the fourth column are given death-rates, which I have calculated on the assumption that Farr's law holds good:—

Density (Persons to a square mile).	Mean crude Death-rate.	Mean corrected Death-rate.	Death-rate according to Farr's Formula.
(1)	(2)	(3)	(4)
138	14·75	12·70	16·36
149	15·73	13·45	16·52
187	16·30	14·48	16·99
214	16·66	15·41	17·28
307	16·92	16·47	18·08
435	17·59	17·35	18·89
662	18·46	18·55	19·90
1281	18·59	19·39	21·62
1803	19·53	20·43	22·56
2437	20·13	21·47	23·43
3299	20·90	22·50	24·33
5329	21·96	23·41	25·84
4295	22·71	24·51	25·15
5722	24·47	26·22	26·07
19584	30·70	33·00	30·40

The above table deals with 632 districts, having a population of 27,488,482, with a mean death-rate of 19·08, and a density of 471 persons to a square mile. The method of obtaining the calculated death-rates in column 4 can be seen from an example: the death-rate for all the districts being 19·08, and their mean density 471 persons per square mile, what will be the death-rate when the density is 19,584 persons per square mile?

$$\frac{m_1}{19{\cdot}08} = \sqrt[8]{\frac{19{,}584}{471}}$$

$$\log. m_1 - \log. 19{\cdot}08 = \frac{\log. 19{,}584 - \log. 471}{8}$$

$$\therefore m_1 = 30{\cdot}40.$$

It will be seen that crude death-rates overstate the mortality of healthy districts, and understate that of unhealthy districts. The death-rate calculated from the density of population and the average death-rate of all the districts by Farr's formula, gives too high a death-rate in all the districts except those presenting the maximum density. It is chiefly after the density has reached a certain degree of intensity that it begins to exert an appreciable effect. As Dr. Ogle says: "This might have been anticipated. For though in crowded communities it may be a matter of vital importance whether there are 500, or 1000, or 2000, or more persons living on a square mile, yet it can scarcely make any difference, so far as health goes, whether in rural districts there be two acres or three acres on an average to each inhabitant. The differences in the death-rates in these sparse populations are determined by other conditions than aggregation."

Causes of High Mortality with Increased Density. The higher death-rates, which are usually associated with increased density of population, are not the direct results of the latter. The crowding of persons together doubtless leads to the risks of fouling of air and water and soil, and to the increased propagation of infectious diseases, and thus directly affects the mortality. But more important than these are the indirect consequences of dense aggregation of population, such as increase of poverty, filth, crime, drunkenness, and other vices, and perhaps more than all, the less healthy character of urban industries. (See p. 181.)

(1) Of the direct influences connected with close aggregation of population, *filth conditions* of air and water and soil are the most important. If the source of water supply is pure and the drainage is good, densely populated towns may be, and are, commonly better off in these matters than rural districts. But atmospheric impurities, especially in the form of decomposing organic matter, are doubtless more rife in town than in country; and Dr. Farr rightly lays special stress on these. Even in towns, the amount of such impurities varies greatly in houses of different sizes, and such differences throw a flood of light on the facts given on p. 162 regarding the higher mortality in one and two-roomed houses. The following table, given in a paper which appeared in the Philosophical Transactions for 1887, by Professor Carnelly and Drs. Haldane and Anderson, as the result of elaborate observations made at Dundee, shows very strikingly the differences in houses of varying size. Taking the average amount (in excess of outside air) of carbonic acid, organic matter,

and micro-organisms respectively in the atmosphere of houses of four or more rooms as unity, then in one and two-roomed houses the relative amount was as follows :—

	Houses of Four Rooms and upwards	Two-room Houses.	One-room Houses.
Cubic Space per person . .	1	0·13	0·11
Carbonic Acid . . .	1	1·5	2·0
Organic Matter . . .	1	1·6	4·4
Micro-Organisms, total . .	1	5·1	6·7
Bacteria	1	3·1	6·9
Moulds	1	5·5	3·0

(2) The more rapid spread of *infectious diseases* is shown by the higher mortality from the chief infectious diseases in large towns, their more rapid spread being partly due to the more frequent opportunities of personal contact, and partly, also, to the fact that a fouled state of the atmosphere and soil facilitates the propagation of infection.

(3) Other diseases, as *phthisis*, are more common in urban than in rural districts. The close connection between phthisis and a foul atmosphere is well established. Dr. Anderson's researches in Dundee, and Dr. Russell's in Glasgow, both show that the mortality from phthisis in these towns is highest among the inmates of three-room houses. The former suggests that the high infantile mortality from other forms of tubercular disease returned as nervous diseases, atrophy, wasting, etc., prevents the growth of young adults (who are most prone to tubercle of the lungs) in the houses with less than two rooms. It may be, also, that in the one and two-roomed tenements, the children leave home earlier than the children living in larger houses.

(4) *Poverty* of the inhabitants of densely populated districts, implying as it does inadequate food and deficient clothing and shelter, has a great effect in swelling their mortality. Dr. Drysdale quoted, in a paper read at the meeting of the British Medical Association in 1887, the lower mean age at death of the industrial classes as evidence that indigence causes a high mortality. The fallacy of this test is exposed on p. 294. A similar objection applies to Dr. Drysdale's argument, based on the statement that among the rich in France, 65 out of every 1000 deaths are due to

tubercular diseases, and 250 per 1000 deaths among the poor. The real question is, What are the relative deaths from tubercular diseases among equal numbers living at corresponding age-groups?

(5) *Other evil social conditions* commonly accompany poverty. Cities are commonly the hotbeds of vice and misery, of crime and drunkenness, as well as of filth and want. The Select Committee on Intemperance (4th Report, 1878) say: "On the whole, in the towns where the drunkenness is greatest, the population is most dense." The density of population and the drunkenness each of them probably stands in the place of both cause and effect.

Accidents are more common and more fatal in cities than in the country. The evil influences of *heredity* should also be mentioned, physical degeneration occurring among those who, generation after generation, are exposed to an unwholesome environment.

(6) The influence of *occupation* and of homes involving exposure to poisonous effluvia and other poisonous agencies, will be considered in the next chapter.

The True Test of Density of Population. In a paper on "The Vital Statistics of Peabody Buildings" (Royal Statistical Society, February, 1891), I showed the inapplicability of Farr's formula to such buildings in which the maximum density of population occurs, but which are under generally favourable conditions of life, notwithstanding this fact. Thus during the year 1889 the number of persons to an acre in London was 58, in the Peabody Buildings 751. What ought to be the death-rate in the Peabody Buildings, that of London being 17·4 per 1000?

$$m' = 17{\cdot}4\left(\frac{751}{58}\right)^{0{\cdot}11998}$$

Consequently $m' = 24{\cdot}21$.

But the actual death-rate of the Peabody Buildings was 16·49 per 1000. Hence the actual death-rate was 7·72, or 31 per cent., lower than the death-rate, calculated on the assumption that mortality varies with density of population according to the above finally modified formula of Farr.

I further pointed out that an essential element in testing the true density of population is *a statement of the number of persons living in each occupied room*. (See also p. 135.) It is probable that this test, combined with a determination of the population on a given area, would give the most trustworthy estimate of density. The two together would determine the probabilities of the incidence of the diseases connected with overcrowding, and of the rapid spread of infectious diseases.

The census returns give information as to the number of houses in each district; and in the 1891 census for the first time information was required as to all tenements with less than five rooms. The definition of "house" in the census instructions was *all the space within the external and party walls of a building*, however many families living in separate tenements or apartments might be comprised within it. A "tenement" was defined as *any house or part of a house separately occupied either by the owner or by a tenant.* No definition of "room" was given, and it is possible, therefore, that in small tenements error might arise by the inclusion of lobbies, closets, etc. The information obtained must, therefore, be regarded as only furnishing rough indications.

At the census of 1891 there were in England and Wales 5,451,497 inhabited houses, and an average number of 5·32 persons to each inhabited house, against 5·38 in 1881, and 5·33 in 1871. The population varies greatly in different parts of the country, and there cannot be considered to be any direct relationship between the average number of persons per house and overcrowding, as the size of houses and the proportion of tenement dwellings varies greatly in different communities. The proportion of persons per house does not, however, appear to vary greatly in individual towns, as shown by the following examples.

POPULATION PER INHABITED HOUSE.

	1881.	1891.		1881.	1891.
Birmingham . . .	5·12	5·01	London . . .	7·84	7·72
Bradford . . .	4·88	4·72	Manchester . .	5·09	5·04
Brighton . . .	6·20	5·93	Norwich . . .	4·45	4·53
Hull . . .	4·77	4·71	Portsmouth . .	5·64	5·43
Leicester . . .	4·93	4·89	Sunderland . .	7·24	7·00

A tenement may, in the terms of the preceding definition, coincide with an entire house; thus in England and Wales, in 1891, there were 1·12 tenements, or distinct occupancies, to each inhabited house.

The following table, summarized from a table on p. 4, vol. iv. of the Census Report, 1891, gives the main facts as to tenements at the time of the last census:

Tenements with	Percentage of English Population in each class of Tenement.	Average Occupants per Room.	Overcrowding.
			Percentage of total Population living in one to four-roomed Tenements, with more than two Occupants per Room.
	(1)	(2)	(3)
1 room	2·2	2·23	1·23
2 rooms	8·3	1·73	3·88
3 „	11·1	1·42	3·28
4 „	23·5	1·16	2·84
5 or more rooms	54·9	—	—
	100·0	—	11·23

It thus appears that 54·9 per cent., or more than half, of the population lived in tenements of more than four rooms; that only 2·2 per cent. lived in single-roomed tenements, 8 3 per cent. in two-roomed tenements, and so on. Column 2 shows that the fewer the rooms in a tenement the larger the proportion of occupants per room. In the census report it is proposed to take as a *standard of overcrowding*, tenements which have more than two occupants per room. This would exclude all single-roomed tenements with not more than two inhabitants, all two-roomed tenements with not more than four inhabitants, and so on. When this is done, it will be seen that 11.23 per cent. of the total population occupy overcrowded tenements, the greatest proportion of these being in two-roomed tenements.

The preceding facts can be studied in detail for each sanitary district in England and Wales in vol. ii. of the *Census Report* (Table 6 in each divisional part).

OVERCROWDING IN RURAL AND URBAN DISTRICTS.

Tenements with	Percentage of Population in each class of Tenement.		Overcrowding. Percentage of total Population living in one to four-roomed Tenements with more than two Occupants per Room	
	Urban Districts.	Rural Districts.	Urban Districts.	Rural Districts.
1 room	2·89	0 44	1·61	0·25
2 rooms	9·38	5·65	4·42	2·48
3 „	11·54	10 06	3·46	2·83
4 „	22·42	26·26	2·82	2·90
5 or more rooms	53·77	57·59	—	—
	100·00	100·00	12·31	8·46

As might have been anticipated, in view of the higher rentals in towns, the preceding table shows a higher proportion of one and two-roomed tenements and of overcrowding, as defined above, in urban districts. When studied in detail, the differences between great towns in respect of proportion of population living in an overcrowded condition are very striking. (See p. 23, vol. iv., *Census Report.*)

Effects of Higher Degrees of Density on Mortality. Dr. J. B. Russell, in an address to the Glasgow Philosophical Society (November, 1888), brought out very strikingly the connection between size of the average house and the general death-rate. Aberdeen, which has 13·6 per cent. of its population living in one room, had the lowest death-rate of eight great Scotch towns, the death-rate rising *pari passu* with the diminution in size of the average house, until we come to Glasgow with 24·7 per cent. of its population living in one room, and the highest death-rate. In comparing the twenty-four districts into which Glasgow is divided, the same general relation was demonstrated. The population of Glasgow in 1885 was 543,295, the number of deaths 13,439. The distribution of population and deaths in the inhabited houses according to their size was as follows :—

Size of House.	Population.	Deaths.	Percentage of	
			Population.	Deaths.
One room . . .	134,728	3636	24·7	27·0
Two rooms . . .	243,691	6325	44·7	47·0
Three ,, . . .	86,956	1747	16·0	13·0
Four ,, . . .	32,742	581	6·1	4·3
Five rooms and upwards .	38,647	434	7·1	3·3
Institutions . . .	6,531	427	1·4	3·2
Untraced . . .	—	289	—	2·2
Whole city . . .	543,295	13,439	100·0	100·0

It will be seen that in both one and two-room houses the deaths were 2·3 per cent. above the due proportion, while in the houses above this size they were all below the due proportion in varying degree. The difference between the distribution of population and deaths may be seen at a glance from Dr. Russell's diagram.

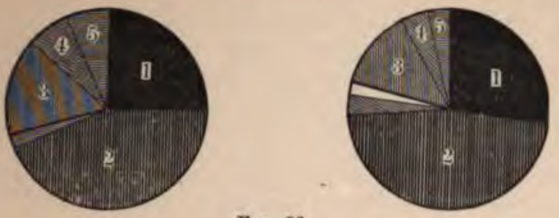


Fig. 20.

Population. Deaths.

The one and two-room houses mentioned above are commonly "made-down houses," *i.e.*, parts of houses of larger size, which are now let separately. In some cases single rooms are divided by wood partitions, and let to two separate families.

If the *death-rates* in these various classes of the population be compared, the deaths in institutions and the unallocated deaths being placed, as in the diagram, along with the deaths contributed by one and two-room houses—it will be found that among those living in one and two-room houses, the death-rate is 27·74 per 1000; among those living in houses of three and four rooms, 19·45; and among those living in houses of five rooms and upwards, only 11·23.

Next as to the *incidence of certain classes of disease* upon these sections of the population, Dr. Russell selected zymotic diseases; diseases of the lungs, including consumption; diseases special to children under five years of age (as convulsions and other diseases of the nervous system, atrophy or wasting, and premature birth); deaths of children from accident and syphilitic disease, "a small class, but one pregnant with meaning." In the following table the rates per 100,000 inhabitants from each of these are shown:—

	One and Two-Room Houses.	Three and Four-Room Houses.	Five Rooms and upwards.
Zymotic Diseases	478	246	114
Acute Diseases of the Lungs (including Consumption) . . .	985	689	328
Nervous Diseases and Diseases of Nutrition in children . . .	480	235	91
Accidents and Syphilis in children	32	11	—
Miscellaneous Unclassified Diseases .	799	764	590
All Causes	2774	1945	1123

The same results are exhibited in the following diagram, in which, the three columns being drawn on the same scale, the comparative general death-rate in the three grades of houses, as well as the comparative prevalence of these classes of disease, can be seen by the height of the columns and their different positions.

It will be observed that in the preceding example no correction is made for varying age-constitution of the population in each class of dwellings. An allowance of uncertain amount must be made for this factor.

It would be a mistake to suppose that the ratio between density and mortality represents an inexorable law incapable of mitigation. That this is not so, is shown by the following

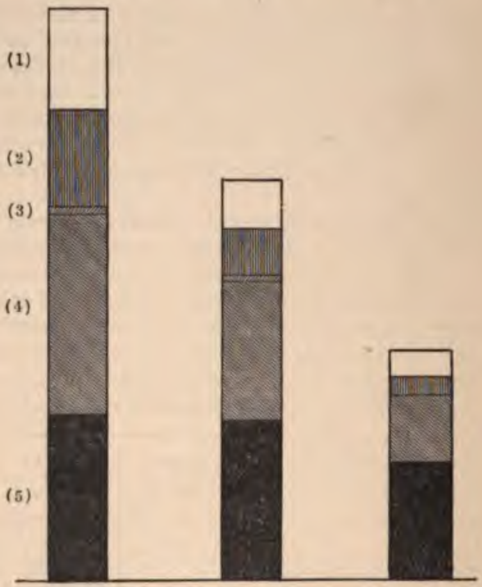


FIG. 21.

(1) Zymotic Diseases. (2) Nervous and other Diseases special to Children. (3) Accidents and Syphilis in Children. (4) Diseases of the Lungs. (5) Miscellaneous.

example, derived from the paper by the author already quoted (pp. 135 and 159).

Peabody Block Dwellings. These dwellings in December, 1890, had an enumerated population of 20,374. These occupied 5071 tenements containing 11,275 rooms. The average number of persons per tenement was 4·03, the average number per room was 1·81. These were occupied by families, the average weekly earnings of which were less than 24*s.* The age-distribution of the population of these buildings was such that the factor of correction was 1·0391 as compared with 1·0615 for London as a whole. The general results of my investigation into the vital statistics of the Peabody Buildings were summarized as follows:—

(1) The death-rate of the Peabody Buildings averaged about 2 per 1000 lower than that of London during the twelve years ending with 1885. During the four subsequent years the death-rate of the Peabody Buildings remained about stationary, while that of London has shown a further decline; thus making the metropolitan death-rate approximate more closely that of the Peabody Buildings.

(2) The death-rate at different groups of ages was lower in the Peabody Buildings than for the whole of London with the exception of the ages 0–5 and 15–25.

(3) The infantile mortality was much lower in the Peabody Buildings than for all London. During the nine years 1882–90 it averaged in London 151·9, in the Peabody Buildings 139·2 per 1000 births.

(4) The death-rate from diarrhœa was slightly lower than, and from enteric fever only half that of the whole metropolis.

(5) On the other hand, the diseases more immediately due to direct infection (scarlet fever, diphtheria, and still more whooping-cough and measles) were more fatal, and therefore probably more prevalent. The two last-named diseases are not admitted into the hospitals of the Metropolitan Asylums Board.

(6) The death-rate from phthisis and other tubercular diseases is slightly higher in the Peabody Buildings than for all London.

(7) Farr's formula as to the increased mortality with increased density of population has no application to the Peabody Buildings.

(8) The true density that should be considered is the number of persons to each room, not the number of persons on a given acre. (See also pp. 135 and 159).

Back-to-Back Houses are still common in several towns in the North of England, and on general grounds it might be expected that the deficient light and ventilation, and the imperfect sanitary arrangements necessarily associated with this style of dwelling, must have an appreciable effect on the health and vitality of their inhabitants. Discrepant statistics have, however, been published, and they are given here as illustrating the difficulty of avoiding errors and fallacies.

Mr. Gordon Smith and Dr. Barry, in their report to the Local Government Board on back-to-back houses, gave the following death-rates from figures furnished by Dr. Tatham.

The Greengates and Regent Road registration sub-districts of Salford were each divided into three groups, as shown in the following table, which will enable the relative mortality of each from various special causes to be seen at a glance :—

	Population.	Death-rate per 1000 living from				
		All Causes.	Pulmonary Diseases, excluding Phthisis.	Phthisis.	Seven Chief Zymotic Diseases.	Diarrhœa.
Greengates Sub-District.						
Group I.—No back-to-back houses	8,713	27·5	6·6	2·8	4·5	1·42
Group II.—Average proportion of 23 per cent. of back-to-back houses	11,749	29·2	7·8	3·3	4·8	1·55
Group III.—Average proportion of 56 per cent. of back-to-back houses	11,405	30·5	7·9	3·6	6·2	2·12
Regent Road Sub-District.						
Group I.—No back-to-back houses	54,264	26·1	5·7	2·7	4·9	1·54
Group II.—Average proportion of 18 per cent. of back-to-back houses	8,773	29·1	7·5	2·7	4·9	1·85
Group III.—Average proportion of 50 per cent. of back-to-back houses	4,380	37·3	8·6	4·5	7·6	2·83

It will be seen that the mortality from all causes, from pulmonary diseases, from phthisis, and from the seven chief zymotic diseases taken together, as well as from diarrhœa alone, increase *pari passu* with the proportion of back-to-back houses.

The difficulty here, as in all similar inquiries, consists in ensuring that the populations thus contrasted have a similar age and sex-constitution, and that apart from the character of the houses the other conditions of life are equal in the contrasted groups.

Dr. J. H. Bell (*Public Health*, vol. iv. p. 143, 1892) advances the opinion that back-to-back houses are not essentially insanitary, and gives a table, of which the following is a summary:—

	No. 1.	No. 2.	No. 3.
Total No. of houses	669	757	703
Total No. of persons	2808	3428	3583
Average No. of square yards to each house	116	122	134
Weekly rental, including rates .	4/6 to 6/6	4/6 to 5/6	5/– to 7/6
Mean annual death-rate per 1000 for 1886-90 (No. 2, 1889-90 only) .	15·8	16·6	17·0

The mean annual death-rate of the entire borough of Bradford, in which the above dwellings were situate, was 21·3 per 1000 in 1886–90.

No. 1 consisted of continuous back-to-back houses.

No. 2 of back-to-back houses in blocks of four.

No. 3 of through houses.

The defects of the above statistics were clearly pointed out by Dr. Arnold Evans, the Medical Officer of Health of Bradford. (*Public Health*, vol. iv. p. 145.) Thus no particular diseases are enumerated, only total death-rates. Further, Dr. Bell "had picked out a few streets here and there containing through houses, and compared their death-rates with those of whole groups of back-to-back houses." Again, many of the through houses selected were old and defective, and situate in narrower streets and at a lower level than the back-to-back houses, and so on.

The statistics least open to objection on this subject are those compiled by Dr. Herbert Jones (*Public Health*, vol. v. p. 347, 1893), in which back-to-back houses in Shipley are contrasted with houses similar in other respects, except in being through-houses, in the neighbouring compact village of Saltaire. The soil, water-supply, aspect, sanitary arrangements, and the building material of the houses in the two groups are identical. The statistics are taken for the six years 1887–92. The density of the population and the ages of the houses were approximately equal in the two groups; so also was the relative amount of pauperism.

SALTAIRE "THROUGH" HOUSES COMPARED WITH SOME BACK-TO-BACK HOUSES.

	Population.	Persons per House.	Persons per Acre.	Percentage of Paupers.	Weekly Rental.	Death-rates per 1000.				
						All causes.	Phthisis.	Diseases of Respiration.	Zymotic.	Diarrhœa.
"Through" .	4,218	4·9	197	·42	3/6 to 5/-	15·6	2·7	3·6	1·08	·22
Back-to-back .	4,155	4·8	222	·47	2/6 to 7/-	21·1	3·4	5·1	1·7	·40
Shipley District	16,000	—	—	—	—	16·2	2·3	4·0	1·7	·22
Back-to-back *A*	2,200	4·7	160	·17	4/- to 7/-	18·1	2·8	4·9	1·3	·22
,, ,, *B*	710	4·7	300	·42	3/- to 3/6	28·1	4·6	7·4	2·9	·84
,, ,, *C*	1,245	4·9	207	1·04	2/6 to 4/6	22·5	4·1	5·7	1·8	.4

For the six years 1887–92.

The table shows excess of zymotic diseases, and still more of phthisis and of respiratory diseases in the back-to back houses. The back-to-back houses were divided into three sections: *A*, with streets twenty-five yards wide; *B*, with streets ten yards wide; and *C*, with streets fifteen yards wide, with the comparative results shown in the above table.

CHAPTER XVII.

OCCUPATION AND MORTALITY.

IN vol. iv. p. 35 *et seq.* of the Census Report, 1891, the unsatisfactory character of the census data as to occupations of the population is pointed out. The instructions contained in each "Householder's Schedule" stated that persons "should state distinctly, not only the general name of the industry in which they are employed, but the particular branch of the industry in which they are engaged, and also the material in which they work, if it be not implied in the name, and if such name be common to several industries," and special illustrative examples were given. But these instructions were largely disregarded, the words "spinner" and "miner," for instance, being given without mention of the material in which the stated work was done. It is evident, as pointed out in the Census Report, that schedules filled up by the householder do not supply data which are suitable for minute classification, or admit of profitable examination in detail. "The most that it is reasonable to expect from data so collected, is that they shall give the means of drawing such a picture of the occupational distribution of the people as shall be fairly true in its main lines, though little value can be attached to the detailed features."

Fresh headings were introduced into the schedules for the 1891 census, to meet the criticisms that in former enumerations distribution had not been kept separate from production, and that masters had not been distinguished from their workmen. It is pointed out, however, on the first head, that the distinction between makers and dealers is not so well marked in actual life as in economical science; a baker or a shoemaker, for instance, may be a person who makes bread or shoes, or a person who merely sells these. To meet the second objection three new columns were introduced, headed respectively "employer," "employed," and "neither employer nor employed," but the returns made under these three heads were "excessively untrustworthy."

Classification of Occupations. At the 1891 census, occupations in combination with ages were abstracted under 349 headings, and then arranged in sub-orders, orders, and classes. Six larger groups or classes were made, viz. :—

Professional,
Domestic,
Commercial,
Agricultural,
Industrial, and
Unoccupied.

The lines of demarcation between these are not very definite, though the classification is useful. Rules were laid down for the guidance of the clerks engaged in tabulating the occupations. As it is desirable that a similar method should be adopted by medical officers of health in arranging the occupational death statistics of their own districts, these rules are given here :—

"Apprentices, journeymen, assistants, and labourers were to be classed under the occupation to which they were apprenticed, or in which they assisted or worked, but messengers, errand boys, porters, and watchmen (excepting railway or government), were not to be so classed, but to go to a special heading provided for them, namely, Messenger, Porter, Watchmen (not Railway or Government).

"Clerks were not classed under the business in which they worked, but under Commercial Clerks. To this, however, bank clerks, insurance clerks, and railway clerks formed exceptions, going respectively to Bank Officials and Clerks, Insurance Service, and Railway Officials and Clerks.

"Persons stated to have retired from business were not classed under their former occupations, but under a special heading 'Retired from business.' To this rule, however, officers in the Army or Navy, clergymen, and medical men were exceptions.

"Patients in lunatic asylums and inmates of workhouses over 60 years of age were not classed by their previous occupations. But paupers under 60, patients in general hospitals, and prisoners were classed by their occupations as being possibly only temporarily debarred from them, and the same rule was applied to persons stated to be 'out of employ' from any stated handicraft.

"When a person was returned with several occupations, the rules laid down for selection of the one under which he was to be classed were, firstly, that a mechanical handicraft or constructive occupation should invariably be preferred to a shopkeeping occupation ; secondly, that, if one of the diverse occupations seemed of more importance than the others, it should be selected; and thirdly, that in default of such apparent difference, the occupation first mentioned should be taken, on the ground that a person would be likely to mention his main business first."

The total number of males, 10 years of age or over, returned as engaged in some definite occupation, was 8,883,254, or 88·9 per cent. of all the enumerated males of those ages; while the total number of females similarly returned was 4,016,230, or only 35 per cent. of all persons of that sex over 10 years of age. It is obvious, however, that this excludes the most important of female occupations, the management of domestic life and the rearing of children.

Methods of Comparison between Occupations. (1) The mean ages at death of those engaged in different occupations are contrasted. This often, however, gives erroneous indications. The mean age at death is governed by the mean age of the living, and it is as much affected by the ages at which people enter and leave any given occupation, and by the increase or decrease of employment, as by its relative salubrity or insalubrity. In a large printing firm known to the writer, all the older *employés* have been replaced by youths from fifteen to twenty-five years of age at lower wages. Such a proceeding will obviously lower the mean age at death, but will by no means demonstrate that this particular printing establishment is carried on under less healthy conditions than formerly.

(2) The proportion between the number engaged in and the number dying in any given occupation, expressed as a rate per 1000, is also fallacious. As we have already seen, p. 103, the death-rate in the general population varies greatly at different groups of ages. The death-rate among those engaged in any one trade or profession would similarly vary according to the relative number at the different ages engaged in it. In other words, it would depend on the *ages of the living*, which would vary in every occupation, (*a*) according as persons enter it early or late in life, and (*b*) according as the numbers that annually enter it increase or decrease. Dr. Farr, in his Fourteenth Report, gives the following example of the mistakes which would follow the adoption of this method. The death-rate of all farmers over 20 years of age was 28 per 1000, of all tailors 20 per 1000; but when tested by a comparison of the death-rate among men of corresponding ages, farmers were much healthier than tailors, as seen in the following table:—

DEATH-RATE PER 1000 AT SIX AGE-GROUPS OF FARMERS AND TAILORS.

Age.	25-	35-	45-	55-	65-	75-
Farmers . .	10·15	8·64	11.09	24·90	55.30	148·62
Tailors . .	11·63	14·15	16·74	28·18	76·47	155·28

(3) The only trustworthy method is to compare the mortality of those engaged in one occupation, and of a given age, with the mortality of those engaged in another occupation, and of a corresponding age.

Statistics of Occupational Mortality. The successive decennial supplements issued from the General Register Office have embodied most valuable information on this subject, and the last one, prepared by Dr. Tatham, is the most complete and detailed of the series. The figures and facts given in the remainder of this chapter are derived almost exclusively from this report.

The three successive decennial supplements of Doctors Farr, Ogle, and Tatham, all adopt the period of life between 25 and 65 years of age as being that in which the influence of occupation is most felt. It is to be remembered, however, that the working period both begins and ends at an earlier date in life in the industrial occupations than in the learned professions.

We have on p. 171 given an illustration showing the fallacy involved in comparing the death-rate of all farmers over 20 with that of all tailors over 20. The following further example is taken from Dr. Tatham's Report. (p. viii.) At all ages over 15, the mortality of all males in 1890-92 was 18·74 per 1000, and that of farmers 19·58. But when the numbers living and dying at each group of ages are compared, the following result is obtained:—

	15-	20-	25-	35-	45-	55-	65 and upwards.
All males . . .	4·14	5·55	7·67	13·01	21·37	39·01	103·56
Farmers . . .	1·30	2·40	4·29	7·03	11·20	23·97	87·81
Mortality of farmers to that of all males taken as 100.	31	43	56	54	52	61	85

The paradox of a high general death-rate among farmers along with a lower death-rate at each age-group is explained by the facts that, while there are nearly three-fourths as many farmers above 65 years of age (with a mortality of 87·8 per 1000) as there are at ages between 25 and 35 (with a mortality of 4·3 per 1000): among all males the number over 65 (with a death-rate of 103·6 per 1000) is less than one-third of the number between 25 and 35 (with a death-rate of 7·7 per 1000).

A similar objection holds if the crude death-rate at the entire age-period 25–65 is taken; as in different occupations there are great variations in age-constitution within these limits. This can be met by the calculation of **death-rates in a standard population.** The standard population thus taken is the number of men aged 25–65 in the whole population, out of whom 1000 deaths would occur in a year, the deaths of 1890–92 and the population of 1891 being taken as the basis.

This number was 62,215 men, viz.:—

22,586 in the age-group 25–35 years
17,418 ,, ,, 35–45 ,,
12,885 ,, ,, 45–55 ,,
8,326 ,, ,, 55–65 ,,

Aged.	Standard Population.	Death-rate per 1000 living in each Age-group among		Calculated number of Deaths in Standard Population among	
		All Males.	Medical Practitioners.	All Males.	Medical Practitioners.
25–35	22,586	6·69	7·67	173	151
35–45	17,418	14·92	13·01	227	260
45–55	12,885	21·04	21·37	275	271
55–65	8,326	34·16	39·01	325	284
				1000	966

The death-rate in each age-group in a given occupation, based on the death statistics for 1890–92 and the census enumeration of 1891, is applied, as shown in the preceding table, to the standard population, and the calculated number of deaths thus obtained gives the "comparative mortality figure" for the occupation in question. For all males it is 1000, for doctors 966, and so on. If the calculated deaths in each of the four age-groups be proportionately divided out according to the causes of death in that age-group, the comparative mortality figure for the several causes of death is obtained. In Table IV. of the last decennial supplement this has been done for each of 100 selected occupational headings, and also for grouped and for subsidiary headings.

Sources of Error in Occupational Statistics. Even when the correct methods described in the last paragraph are adopted, there are certain sources of possible error in the vital statistics of occupation.

(1) The vagueness with which the occupation may be entered in the census or mortality returns has been already mentioned. For this reason only well-defined occupations are taken in the decennial supplement of the Registrar-General.

(2) A still more serious difficulty is pointed out by Dr. Ogle, for which there appears to be no remedy, and which must always to some extent diminish the value of all calculations of the death-rate in different industries. Many trades, as that of a blacksmith or miner, require great muscular strength, and must be given up by persons who become weakly; and the latter may then raise the mortality of the lighter occupations to which they resort. Thus the death-rate of the more laborious occupations is unfairly lowered as compared with the death-rate (*a*) of those engaged in lighter occupations, or (*b*) of those who are returned as having no occupation, or (*c*) of those who have to betake themselves to odd jobs, as general labourers, messengers, costermongers and street-sellers.

(3) Another flaw in occupational death-rates, when taken as tests of relative healthiness, is the fact that those who follow the several industries do not start on equal terms as regards healthiness. A weakling will not become a navvy, but a shopman or tailor by preference. The occupations demanding great muscular strength and activity, to some extent then, consist of picked men, stronger at the commencement, and maintained up to a certain standard by the fact that weaklings are drafted into lighter occupations.

After making full allowance for the preceding difficulties, the death-rates of different occupations still furnish most valuable indications of the relative salubrity of different occupations; and while small differences may be accidental, large differences must be taken as representing real differences of healthiness in the various occupations.

Mortality in Different Occupations. It is impossible here to reproduce the elaborate tables given in Part II. of the *Supplement to the Fifty-fifth Annual Report of the Registrar-General*, p. cxix. *et seq.* We must content ourselves with a statement of the comparative mortality figures in some of the chief occupations, and refer the reader to the above-mentioned tables for further particulars and for the actual death-rate of persons engaged in each occupation at each ten-yearly age-group.

A preliminary difficulty arises in comparing Dr. Tatham's comparative mortality figures for 1890–92 with those of Dr. Ogle for 1880–82, based on the fact that the latter were obliged to be calculated on the death-rates in the two age-groups 25–45 and 45–65, applied to a population of 64,641 men, of whom 41,920 were between 25 and 45, and 22,721 were between 45 and 65 years of age; while, in the former, death-rates for four age-groups were available, and the standard population of 61,215 men had a slightly different age-constitution from the above. For this reason Dr. Tatham has calculated "modified mortality figures" by taking the death-rates at ages 25-45 and 45–65 in the chief occupations, and applying them to the standard population in 1891 of 61,215 men, of whom 40,004 were between 25 and 45, and 21,211 between 45 and 65 years of age. In the following table these three sets of comparative mortality figures are given, and in the first column is given the more accurate comparative mortality figure for 1890–92, based on four age-groups:—

COMPARATIVE MORTALITY FIGURES OF MALES FROM 25 TO 65 YEARS OF AGE, ENGAGED IN DIFFERENT OCCUPATIONS.

Occupation.	Comparative Mortality Figure			
	Calculated on Four Age-groups.	Calculated on Two Age-groups (Modified Mortality Figure).		
	1890–92.	1890–92.	1880–82.	1860, '61, '71.
All Males	1000	1000	942	960
Males in Selected Healthy Districts . . .	679	693	—	—
Occupied Males . .	953	947	910	—
Unoccupied Males . .	2215	2338	2065	—
Clergyman, Priest, Minister	533	547	524	605
Gardener, Nurseryman, Seedsman . . .	553	568	564	642

Table continued on next page.

Occupation.	Comparative Mortality Figure			
	Calculated on Four Age-groups.	Calculated on Two Age-groups (Modified Mortality Figure).		
	1890-92.	1890-92.	1880-82.	1860, '61, '71.
Farmer, Grazier . .	563	591	595	673
Schoolmaster, Teacher .	604	571	677	893
Grocer, etc. . . .	664	664	726	744
Labourer, etc., in Agricultural Districts . .	666	681	660	—
Coal-miner (Derby & Notts.)	727	693	691	—
Sawyer	768	789	802	798
Artist, Engraver, Sculptor, Architect . . .	778	777	868	955
Carpenter, Joiner . .	783	779	772	831
Barrister, Solicitor . .	821	820	793	882
Fisherman . . .	845	843	752	786
Shopkeeper (including stationer, chemist, tobacconist, fishmonger, fruiterer, grocer, draper, ironmonger) . .	859	856	827	—
Medical Practitioner .	966	957	1058	1073
Tailor	989	999	990	1043
Wool, Worsted Manufacture (W. Riding) . .	996	986	971	—
Bricklayer, Mason, Builder	1001	1002	913	1033
Coal-miner (Lancashire) .	1069	1026	874	—
Law Clerk . . .	1070	1028	1084	1536
Butcher	1096	1066	1103	1130
Printer	1096	1048	1009	1144
Plumber, Painter, Glazier	1120	1091	1132	1234
Cotton, Linen Manufacture (Lancashire) . .	1176	1122	1024	—
Carman, Carrier . .	1284	1247	1201	—
Slater, Tiler . . .	1322	1305	888	1078
Tool, Scissors, File, Saw, Needle-maker . .	1412	1398	1198	1169
Brewer	1427	1407	1282	1552
Innkeeper, Inn, Hotel-servant	1659	1665	1525	1490
Potter, Earthenware, etc., Manufacture . .	1706	1639	1638	1390
File-maker . . .	1810	1791	1569	1548

The preceding table is to be read as follows. The same number of men, aged 25–65 (having equal numbers at the various inclusive ages), that would give 1000 deaths among all males, would give 533 among the clergy, 1810 among file-makers, and so on.

Occupational Mortality Distributed according to Causes. It is only possible here to summarize some of the chief results. We may first compare *occupied and unoccupied men*. The preceding table shows the comparative mortality figure of the former to be 953, of the latter, 2215. Doubtless at the earlier ages, the bulk of the unoccupied are those who are physically unfit for employment; later on they become eliminated by the high death-rate among them, but their place is partially taken by recruits from the ranks of the employed.

The following table (p. xvi., *op. cit.*) shows how in each case the comparative mortality figure is made up:—

Cause of Death.	Occupied Males.	Unoccupied Males.
Diseases of Nervous System	82	630
Phthisis	185	448
Diseases of Circulatory System	126	240
Influenza and Diseases of Respiratory System (except Bronchitis)	166	266
Cancer	44	96
Diseases of Urinary System	41	82
Alcoholism and Diseases of Liver	40	76
Diseases of Digestive System (except Liver Diseases)	28	43
Accident (including Plumbism)	57	81
Suicide	14	28
Bronchitis	88	84
Rheumatic Fever	7	2
All other causes	75	139
All Causes	953	2215

In the table on p. 176, some of the chief occupations are ranged in order of their comparative mortality. It is interesting to follow out the occupations there enumerated, and discover to the comparative immunity from or excess of what particular diseases they owe their relative positions. This can be done by means of Table IV., *op. cit.*, p. cxlv. *et seq.*, from which the following typical examples are taken:—

COMPARATIVE MORTALITY OF MALES, 25–65 YEARS OF AGE, IN DIFFERENT OCCUPATIONS, FROM ALL CAUSES AND FROM SEVERAL CAUSES, 1890–92.

Occupation.	All Causes.	Influenza.	Alcoholism.	Rheumatic Fever.	Gout.	Cancer.	Phthisis.	Diabetes.	Diseases of Nervous System.	Valvular Disease of Heart.	Aneurism.	Other Diseases of Circulatory System.	Bronchitis.	Pneumonia.	Pleurisy.	Other Diseases of Respiratory System.	Hernia.	Diseases of Liver.	Other Diseases of Digestive System.	Bright's Disease.	Other Diseases of Urinary System.	Plumbism.	Accident.	Suicide.	All other Causes.
All Males . . .	1000	34	13	7	2	47	192	7	102	24	6	102	88	107	7	22	3	29	26	28	16	1	56	15	66
Clergyman, Priest, Minister . . .	533	36	2	11	3	35	67	17	69	16	2	64	11	45	5	8	0	18	26	27	12	—	9	7	43
Barrister, Solicitor .	821	45	12	8	4	60	116	28	104	27	3	88	17	55	1	16	1	55	29	38	10	—	22	18	64
Medical Practitioner .	966	51	14	3	8	43	105	22	122	28	6	96	12	93	7	13	—	60	49	56	23	—	37	41	77
Draper . . .	1014	44	14	11	—	49	260	12	102	27	3	105	58	92	5	26	—	33	29	26	10	—	19	15	74
Carman, Carrier . .	1284	45	17	9	1	59	195	4	93	27	6	133	149	184	13	29	3	27	33	27	14	0	128	15	73
Innkeeper . . .	1659	46	94	16	12	53	311	19	148	30	7	153	89	165	10	34	5	174	42	59	27	0	47	29	89
Potter	1706	42	9	8	1	35	333	9	123	43	6	178	378	135	8	149	3	32	31	45	18	17	20	16	69
File-maker . . .	1810	40	4	—	4	39	402	12	212	41	0	154	188	197	4	34	—	36	36	82	22	75	30	31	149

(For the same data respecting other occupations see Part II. *Supplement to Fifty-fifth Annual Report of the Registrar-General*, Table IV. p. cxlv. *et seq.*).

The comparative mortality figure among all occupied males (953) from **Influenza** is 33. As might be expected, the highest comparative mortality figures from this disease are among those most exposed to infection. Thus medical practitioner (966) 51, innkeeper, London (1685) 61, milk-seller (1061) 60. The lowest are tin-miners (1409) 12, mechanic (399) 12.*

Alcoholism will be separately considered.

Rheumatic Fever is responsible for a comparative mortality figure among all occupied males of 7, varying from 2 for hatters (1109) and brass-workers (1088), 3 for shoemakers (920) and locksmiths (925), to 10 for teachers (604), 11 for clergymen (533), 19 for publicans (1642), 25 for mine service (1021), 26 for hotel servants (1583), and 28 for copper-miners (1230).

Gout causes a comparative mortality of 2 among occupied males, varying from 0 for fishermen (845), drapers (1014), hatters (1109), bookbinders (1060), and some other occupations, to 7 for saddlers (924), 10 for gunsmiths (1228) and plumbers (1120), and 16 for innkeepers in agricultural districts (1320).*

Cancer is responsible for a comparative mortality figure of 44 among occupied males, varying from 22 among paper manufacturers (904), 26 among Welsh coal-miners (1145), and 36 among farmers (563), to 60 among barristers (821), 63 among commercial travellers (961), 70 among brewers (1721) and London innkeepers (1685), 73 among tallow, glue, and soap manufacturers (1109), and 156 among chimney-sweeps (1311).

For **Phthisis** the comparative mortality figure for occupied males is 185, the lowest on the list being clergymen and ministers 67 (533), railway engine drivers and stokers 76 (810), farmers and graziers 79 (563), brick burners 84 (741), coal merchants 95 (803), and coal-miners 97 (925); the mortality figure rising until it becomes 325 for dock and wharf labourers (1829), and for messengers and porters (1222), 331 for copper-miners (1230), 333 for potters (1706), 336 for tool, scissors, file, etc. makers (1412), 380 for lead-miners (1310), 443 for costermongers and hawkers (1652), and 476 for inn and hotel servants (1725). It will be noted that three of the occupations in which the lowest mortality from phthisis occurs are concerned in the manipulation of coal.

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* In each example the comparative mortality *from all causes* of those engaged in a particular occupation is given in brackets for convenience of reference.

The comparative mortality figure for **Diabetes** is 7 for all occupied males. It is only 1 for messengers and porters (1222), 3 for locksmiths and gasfitters (925), and for shipwrights (713); but ranges up to 17 for the clergy (533), for artists and architects (778), and for brewers (1427), 19 for innkeepers (1642), 22 for medical practitioners (966), and 28 for barristers and solicitors (821).

Diseases of the Nervous System show a comparative mortality figure of 82 among occupied males. Among the lowest are maltsters 44 (884), rope and cord makers 45 (928), farmers 51 (563), farm labourers 53 (632); among the highest, barristers and solicitors 104 (821), railway stokers and dockmen 114, medical practitioners 122, law clerks 123, brewers 125, innkeepers 160, file-makers 212, lead-workers 232.

Valvular Disease of the Heart causes a mortality figure of 23 among all occupied males, varying from 9 for maltsters (884), 10 for law clerks (1070), and 13 for chimney-sweeps, to 27 for lawyers, 28 for doctors, 30 for teachers (604), 37 for railway stokers (810), 40 for lead-workers (1783), 43 for hairdressers (1099) and for potters (1706), 44 for fishermen (845), and 47 for manufacturing chemists (1392).

For **Aneurism** the figure for all occupied males was 6, varying from 0 for farmers (563), 1 for stationers, etc. (833), 2 for clergy (533), 3 for maltsters (884) and drapers (1014), to 8 for artists (778) and musicians (1214), 9 for coachmen (1153), 13 for inn-servants (1725), 14 for dock labourers (1829) and gunsmiths (1228), 18 for bargemen (1199) and seamen (1352), and 28 for copper-miners (1230).

Bronchitis produced a mortality figure of 88 for all occupied males. The lowest from this cause were 11 clergy (533), 12 doctors (966), 15 farmers (563); the highest coal-miners 114 (925), general labourers 140 (1221), coalheavers 180 (1528), costermongers 192 (1652), tool, scissors, etc. makers 202 (1412), glass manufacture 222 (1487), manufacturing chemists 249 (1392), potters 376 (1706).

The mortality figure for **Pneumonia** among occupied males was 105, varying from 43 for teachers (604), 45 for clergy (533), 61 for artists (778), 93 for doctors (966), to 158 for innkeepers (1642), 184 for carmen (1284), 197 for hotel servants (1725), 220 for dock labourers (1829), 248 for iron and steel manufactures (1301), and 249 for coalheavers (1528).

Diseases of the Liver had a comparative mortality figure of 27 for all occupied males, being 18 for the clergy, for railway guards and porters, for corn millers and for miners, 13 for farm labourers, and ranging up to 55 for lawyers, 59 for brewers, 60 for doctors, and 201 for publicans.

Bright's Disease. Comparative mortality figure among all occupied males 27, hosiers 8, farm labourers 12, farmers 18, clergy 27, lawyers 38, brewers 55, doctors 56, innkeepers 62, file-makers 82.

Plumbism. Comparative mortality figure among all occupied males 1, amounting to 15 among tool, scissors and saw-makers, 7 among potters, 75 among file-makers, and 211 among lead-workers.

Accident. Comparative mortality figure among all occupied males 56, teachers 8, clergy 9, grocers 16, drapers 19, railway guards and porters 137, coal-miners 141, coalheavers 144, seamen 202, bargemen 223.

Suicide. Comparative mortality figure, all occupied males 14, tanners and railway drivers and stokers 3, clergy and bargemen 7, corn millers 8, lawyers 22, chemists 31, innkeepers 32, doctors 37.

We may summarize, in conclusion, some of the most important facts bearing on the influence of foul air, of dust, lead-poisoning, and alcoholic excess, on the health of those exposed to their effects.

Effects of breathing Foul Air. The following table (*Supplement to the Fifty-fifth Annual Report of the Registrar-General*, part ii. p. xcix.) refers to the statistics of 1890–92, and gives for certain selected occupations the evidence showing the damage done by impure but not necessarily dust-laden air, in the course of these occupations.

"For each of these occupations the figures indicating the mortality from phthisis, and from diseases of the respiratory and circulatory systems are separately shown: and in the third column the figures representing the mortality from phthisis and respiratory diseases together are compared with the figure for agriculturists, the latter being taken as 100. The occupations in the list have been arranged in the ascending order of their mortalities from phthisis and respiratory diseases combined."

Occupation.	Phthisis and Diseases of Respiratory System.		Phthisis.	Diseases of Respiratory System.	Diseases of Circulatory System.
	Mortality Figure.	Ratio.	Mortality Figure.		
Agriculturist	221	100	106	115	83
Engraver—Artist	279	126	146	133	96
Shopkeeper (Class)	350	158	172	178	117
Commercial Clerk	390	176	218	172	115
Butcher	404	183	195	209	157
Saddler	417	189	248	169	133
Watchmaker	427	193	234	193	94
Shoemaker	437	198	256	181	121
Draper	441	200	260	181	135
Tobacconist, Tobacco Manufacturer	461	209	280	181	109
Tailor	466	211	271	195	121
Hairdresser	489	221	276	213	179
Hatter	511	231	301	210	141
Musician	522	236	322	200	191
Printer	540	244	326	214	133
Bookbinder	543	246	325	218	115

Contrary to the experience of two-thirds of the occupied male population of England and Wales, phthisis is more fatal than are other diseases of the respiratory system in thirteen out of fifteen of the groups of workers in the preceding table.

Effects of breathing Dust-laden Air. In the following table, extracted from the same source as the last, similar facts are set forth for occupations in which there is special liability to injury from the inhalation of solid particles :—

Occupation.	Phthisis and Diseases of the Respiratory System.		Phthisis.	Diseases of Respiratory System.	Diseases of Circulatory System.
	Mortality Figure.	Ratio.	Mortality Figure.		
Agriculturist . . .	221	100	106	115	83
Ironstone-miner . .	294	133	90	204	84
Carpenter . . .	326	148	172	154	106
Coal-miner . . .	366	166	97	269	120
Corn Miller . . .	366	166	143	223	112
Baker, Confectioner .	392	177	185	207	130
Blacksmith . . .	392	177	159	233	136
Wool Manufacture . .	447	202	191	256	131
Tin-worker . . .	451	204	217	234	124
Carpet, Rug Manufacture .	471	213	226	245	87
Bricklayer, Mason, Builder	476	215	225	251	130
Cotton Manufacture .	540	244	202	338	152
Lead-worker . . .	545	247	148	397	272
Chimney-sweep . .	551	249	260	291	142
Stone Quarrier . .	576	261	269	307	137
Zinc-worker . . .	587	266	240	347	126
Iron and Steel Manufacture	645	292	195	450	162
Gunsmith . . .	649	294	324	325	153
Copper-miner . . .	678	307	331	347	121
Copper-worker . .	700	317	294	406	186
Lead-miner . . .	705	319	380	325	142
Glass Manufacture . .	740	335	295	445	157
File-maker . . .	825	373	402	423	204
Tin-miner . . .	885	400	508	377	95
Cutler, Scissors-maker .	900	407	382	518	167
Potter, Earthenware Manufacture . .	1001	453	333	668	227

Dr. Ogle, in his remarks concerning the effects of dust on the lungs in 1880–82, pointed out that the dust of coal and of wood was the least injurious, while the dust of metals and of stone was the most injurious, flour dust and the dust given off and inhaled in textile factories occupying an intermediate position as regards injury to health. Dr. Tatham's figures, just given, on the whole confirm this generalization. The favourable position of coal-miners is particularly noteworthy.

Effects of Chronic Lead-poisoning. Lead-poisoning is evidenced particularly in the following occupations, the comparative mortality figures for plumbism being 211 for lead-workers, 75 for file-makers, 21 for plumbers, 18 for glaziers and painters, 17 for potters, 12 for glass-makers, 8 for copper-workers, 7 for coach-makers, 6 for gasfitters and locksmiths, 5 for lead-miners, 3 for printers, cutlers, and wool manufacturers, as compared with 1 for all occupied males. This does not exhaust the evil, the figures under the head of urinary diseases, diseases of the nervous system and gout, showing a great excess in most of the above occupations.

Effects of Alcoholic Excess. The death returns under the head of alcoholism are notoriously imperfect. Cirrhosis of the liver forms a better index of alcoholic excess. It is well known, however, that the persistent excessive consumption of alcoholic drinks damages most of the viscera of the body. Hence diseases of the nervous system, phthisis, urinary diseases, gout, and suicide are excessive in their incidence on the occupations in which alcoholic indulgence is common. In the following table the mortality of occupied males in 1890–92 at ages 25–65 years, from each cause of death, has been expressed as 100; and the mortality in each several industry has been reduced to a figure proportional to that standard.

	Alcoholism and Diseases of Liver.	Alcoholism.	Diseases of Liver.	Gout.	Diseases of Nervous System.	Suicide.	Phthisis.	Diseases of Urinary Organs.
Occupied Males .	100	100	100	100	100	100	100	100
Coachman, Cabman .	153	215	122	300	100	143	124	132
Costermonger . .	163	277	107	150	170	100	239	171
Coalheaver . .	165	223	137	—	120	50	116	122
Fishmonger . .	168	215	144	150	109	150	86	120
Musician . .	168	223	141	450	135	164	174	141
Hairdresser . .	175	269	130	400	109	250	149	78
Dock Labourer .	195	400	96	150	139	157	176	166
Chimney-sweep .	200	454	78	—	100	221	141	144
Butcher . . .	228	269	207	300	128	164	105	117
Brewer . . .	250	315	219	500	152	121	148	190
Inn Servant . .	420	815	230	550	132	179	257	188
Innkeeper . .	733	708	744	600	195	229	140	220

CHAPTER XVIII.

MORTALITY FROM ZYMOTIC DISEASES.

WE have in the preceding chapters shown the effect produced by various social and other conditions on the general mortality. In the next place we must consider the mortality from individual diseases and from groups of diseases. In the first place, as to the **methods of stating** this mortality. This will vary according to the object in view. (1) The first plan, useful for purely medical purposes, consists in stating the *proportion of deaths to persons attacked* by any given disease. This method is of importance as indicating the degree of virulence of a particular disease, and because from the results thus obtained deductions can be drawn concerning the effect of a particular line of treatment. We may point out the liability of this method to error before passing on to the statement of methods usually adopted by vital statisticians.

(*a*) The number of facts manipulated is often so small as not to warrant exact conclusions. Thus in a small outbreak of enteric fever, investigated by the author, of 21 total cases, 15 were treated either at home or in one public institution, while 6 were treated in another public institution. Of the former none died, while 2 of the latter proved fatal. The difference in fatality was almost certainly due to causes other than the methods of treatment, and any inferences as to skill of treatment would be altogether fallacious Speaking generally, therapeutical results or etiological theories, advanced on the strength of *percentages from a small number of cases, must be accepted with caution.* (See also page 323.)

(*b*) The two groups compared may have a different age and sex-constitution, and it is a notorious fact that the death-rate from nearly all diseases is largely influenced by these factors, and especially by age.

Thus in typhus fever the percentage mortality (fatality) varies from 2·28 at ages 10–15, and 3·59 at ages 5–10, to 49·62 at ages 50–55, and still greater at higher ages. In enteric fever the fatality varies from 11·28 per cent. at ages 5–10, and 12·06 under 5 years of age, to 26·61 at ages 40–45, and 45 per cent. at ages 55–60. (See pp. 237 and 606, *Murchison's Treatise on Continued Fevers*, Third Edition, 1884.)

Similarly whooping-cough is much more fatal among female than among male children. Thus in 1881–90 the death-rate from this disease averaged 3672 per million female children under 5 years of age, as compared with 3066 among male children at the same age. In the next group of ages 5–10 the death-rates per million living were 155 and 100 among female and male children respectively.

(*c*) By splitting up the deaths at all ages into groups at different ages, the number of individual facts at each age is reduced, and thus the fallacy due to paucity of data may be introduced. This, however, is preferable to the lumping together of sets of facts which are not comparable with each other. In stating percentages, *the number of facts on which they are founded should always be given*, as their trustworthiness can then be gauged.

(*d*) In the case of infectious diseases, the character of the particular epidemic must be taken into account. One epidemic of diphtheria may differ in virulence from another, and comparison between methods of treatment in the two epidemics would be to that extent vitiated. Similarly, it would be unfair to compare the treatment at the beginning of an outbreak of cholera, when 50 per cent. of those attacked commonly die, with the treatment in the later and milder period of the epidemic.

(2) The mortality from any given disease or group of diseases may be stated as *a proportion to the deaths from all causes*. This method is, however, essentially fallacious, as it constitutes a ratio between two factors, of which both are variable, viz., the mortality from the specified disease, and the mortality from all causes. Dr. Ransome gives the following example of its fallacious character. Suppose a town of 100,000 with 2000 annual deaths, of which 500 are caused by phthisis. Here the general death-rate is 20 per 1000; the death-rate from phthisis is 5 per 1000 living, and the deaths from phthisis form one-fourth of the total deaths. In another town, having the same population, the total deaths are 4000, and therefore the death-rate 40 per 1000 inhabitants; the deaths from phthisis are 1000, and therefore the death-rate from phthisis is 10 per

1000; but the proportion of the phthisical to the total mortality is one-fourth, as before. In the second town, therefore, there is by the latter test apparently no worse condition, so far as phthisis is concerned, than in the first, though matters are really twice as bad.

In annual reports of medical officers of health the zymotic mortality is frequently stated as a percentage of deaths from all causes. Thus, if in one year the zymotic mortality forms 11 and in the next year 15 per cent. of the total mortality from all causes, it is evident that the relative mortality might be increased either by a diminution in total deaths or an increase in zymotic deaths, though the inference to be drawn in the two cases would be very different.

It is occasionally convenient to know the percentage of deaths due to different causes, in order to estimate the relative magnitude of the different causes of death; but this method cannot be employed with propriety in comparing one community with another, or even in comparing the records of the same community in successive years.

(3) *The deaths from each individual cause may be stated per thousand or per million of the entire population.*

Tables on this basis for the principal zymotic diseases will be found on p. xcvi. *et seq.* of the *Annual Report of the Registrar-General*, 1896, for the whole of England and Wales, and on pp. xx–xxvi. of the *Annual Summary* for 1896 for 33 great towns and 67 other large towns, or in the corresponding parts of the reports for other years.

Here again the importance of stating the number of facts on which the death-rate is based must be emphasized. A single fatal case of diphtheria imported into a hamlet with 200 inhabitants would mean a death-rate from that one cause alone of 5 per 1000, and if the rate were published apart from the data on which it was based, an erroneous impression would be produced. A single year's returns are apt to make a small district come out very badly or too favourably.

As the age-constitution of the population varies but slowly, death-rates per 1000 of the entire population are sufficiently accurate for most purposes and for the majority of diseases. When, however, special accuracy is required, and always when dealing with certain diseases,

(4) *The deaths from each individual disease at a given age-group should be stated per* 1000 *of the population living at the*

same age-group. Thus a comparison of the death-rate per 1000 of entire population from measles in a residential suburb with the corresponding death-rate from measles in a thickly-populated artisan district would be unfair, owing to the higher proportion of young children in the latter, among whom measles is chiefly fatal.

The method adopted in the Registrar-General's reports of stating the diarrhœal death-rate in terms of the entire population is especially open to objection. This can be made clear by two examples. The death-rates in the first column of the following table are taken from the *Annual Summary of the Registrar-General* for 1896; the second column has been calculated by me:—

Place.	Deaths from Diarrhœa	
	Per 1000 of Population.	Per 1000 Births.
Dover	·42	15·7
Hastings	·26	14·1
Percentage excess of Dover over Hastings	+61·5 %	+11·4 %
Huddersfield	·26	12·9
Newcastle-on-Tyne	·51	16·4
Percentage excess of Newcastle over Huddersfield	+96·1 %	+27·1 %

Thus by the less exact method the percentage excess of Dover and Newcastle respectively is 61·5 and 96·1 per cent., instead of 11·4 and 27·1 per cent., as indicated by the method which more nearly approximates to the truth. About 80 per cent. of the total deaths from diarrhœa occur under one year of age; and if the deaths from diarrhœa in the third quarter of the year be taken as a more accurate index of the prevalence of epidemic diarrhœa, the proportion of deaths under one year of age is still higher, and their statement in terms of the number of births an even closer approximation to the truth.

Zymotic Death-rate. The term *Zymotic* was introduced by Dr. Farr, and it is practically so convenient that we propose to adhere to it, although *Specific Febrile Diseases* is perhaps a more correct designation. The diseases comprised under this head have such a varied origin, that a rate compounded of all of them would be of but secondary importance. The Registrar-General gives the **death-rate from the seven chief infectious diseases** (small-pox, measles, scarlet fever, diphtheria, whooping-cough, fever, and diarrhœa), and this is usually described as the zymotic death-rate. As a test of sanitary condition, this rate possesses considerable value, which must not, however, be exaggerated. To begin with, the prevalence of such diseases varies greatly in different districts, according to the proportional number of young children in each, apart altogether from any differences in sanitary or social conditions. Then again, although whooping-cough and measles have a much greater effect in increasing the mortality than typhus and enteric fever, they are much less amenable to sanitary measures than the latter diseases. An accumulation of children unprotected by a previous attack of the two first of these diseases, along with a spell of severe weather, might cause a great increase of zymotic mortality in any given locality, without its being of necessity in a less healthy condition than another which had escaped. The zymotic death-rate should always be separated into its seven component parts, as well as stated as a whole.

Periodicity in Epidemic Diseases. In stating annually the mortality from some of the infectious diseases, it should be remembered that their infrequent appearance in the death-returns may be caused by the fact that there are but few in the population who have not purchased immunity by a previous attack. After a large epidemic of measles, or whooping-cough, or scarlet fever, there is often a lull for several years. Dr. Ransome has investigated the influence of *cyclical waves*, which appear to be independent of the accumulation of unprotected persons. From the Swedish tables of mortality (Epidemiological Society Transactions, 1881–82) he has constructed charts, which show that, in the case of scarlet fever, there is not only a short cycle of from four to six years, but also a long undulation of from 15 to 20 years or more, "which may be likened to a vast wave of disease upon which the lesser epidemics show like ripples upon the surface of an ocean swell."

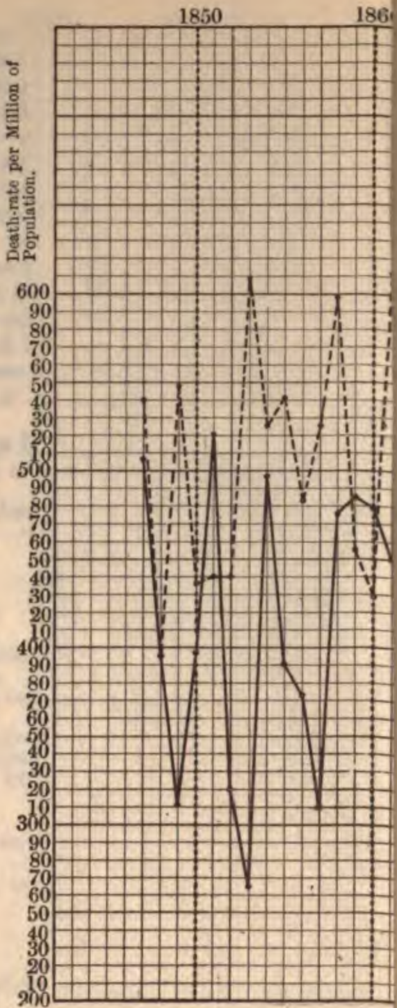
Dr. Whitelegge, in extending Dr. Ransome's researches on periodicity, has pointed out certain distinctive features between the shorter and longer cycles. The shorter or "superadded" disease waves are not attended by any regular and progressive increase and subsequent decrease of virulence. They are, in fact, waves of mere prevalence, as in epidemics due to infected milk or water. The longer or fundamental disease waves are characterized, on the other hand, by an increase both of prevalence and severity, as shown by increased fatality of the disease and a tendency for persons to be attacked at ages which are usually little prone to the disease in question.

Measles has been shown by Dr. Whitelegge to be characterized by minor and major epidemics, the former "occurring every year or two, and in a sense mechanically," and the latter occurring at longer intervals, and possibly due to progressive alterations in the intensity of the measles virus.

Average Death-rates. In the following table the average death-rates from certain diseases or groups of diseases are given:—

ANNUAL DEATHS PER 1,000,000 PERSONS LIVING.

	1871-80.	1881-90.	1891-95.
Small-pox	234	45	20
Measles	378	440	408
Scarlet Fever	716	334	182
Diphtheria	121	163	253
Whooping-cough	512	450	398
Typhus	57	14	4
Enteric Fever	322	196	174
Continued Fever	103	25	8
Diarrhœal Diseases	935	674	652
Cancer	468	589	712
Phthisis	2116	1724	1464
Other Tubercular Diseases	747	696	660
Diabetes	38	57	69
Diseases of the Nervous System	2789	2592	2288
" " Circulatory System	1339	1576	1677
" " Respiratory System	3899	3729	3747
" " Digestive System	1165	1104	1116
" " Urinary System	350	435	453
Puerperal Fever, Child-birth	167	153	167
Violence	733	648	663
All other and unstated Causes	4083	3436	1623
All Causes	21272	19080	18738



Annual Death-rate from Measles and W

Face page 191.

The above table is useful to show the relative death-rates from certain diseases, and to indicate the general tendency towards increase or decline in mortality from them. In accurate investigations into the prevalence of infectious diseases, especially those dealing with limited districts, average death-rates should be eschewed, the death-rate for each year being plotted out in diagrammatic form, so that the exact course of the disease may be traced. It may be desirable occasionally to plot out the monthly or quarterly incidence of a disease. By this means the influence of an epidemic in disturbing the usual seasonal incidence of each infectious disease can be detected.

It is particularly dangerous to compare the mean death-rate of two cities or other places for periods of years which do not coincide in the two instances. Even when an average is struck for the same series of years, there remains the fallacy that one place may have happened to have, say, three epidemics, and another four during the given term of years. It might thus happen, for instance, that if two or three additional years had been added to the series, the place of the two cities would have been reversed as regards their average death-rate from the disease in question.

Measles. The death-rate from this disease in England has varied between 1847 and 1896 from 602 per million persons living in 1887 to 257 in 1875, averaging 441 in 1881–90. In London it has varied from 884 in 1858 and 942 in 1864 to 246 in 1852, averaging 636 in 1881–90.

Fig. 22 shows that the average annual mortality from measles has not fluctuated greatly in the course of the last fifty years. It is more fatal in urban than rural districts. The highest mortality from measles is at the ages 0–5. In the decennium 1881–90 it was 3131 per million persons living in England at these ages, only 271 in the next age-period 5–10, and 23 in the age-period 10–15. The death-rate per million living at each year of age under 5 in 1881–90 was 3365 under 1 year, 2916 at age 2–3, 1684 at age 3–4, and 1031 at age 4–5. It is evident that the higher death-rate at the younger ages might be due to the larger number attacked at these ages, or to a greater fatality among those attacked, or to both these combined. The data for elucidating this point are scanty, being only obtainable for districts in which measles is compulsorily notifiable. Even in such districts it is more likely in the case of measles than of other notifiable diseases that cases escape notification, owing to the lack of medical attendance in a large proportion of cases. In Edinburgh in 1880–89 the fatality from measles varied from 5·9 per cent. in 1880 to 1·5 per cent. in 1881, averaging 3·1 per cent. for the ten years.[*] The cases are not classified according to age.

Dr. T. Thomson[†] gives the statistics for a certain district having an estimated mean population March, 1892, to March, 1894, of 35,606, during nearly the whole of which time measles was epidemic in the district.

Age-groups.	Estimated mean Population.	Measles.		
		Attack-rate per 1000 living.	Death-rate per 1000 living.	Fatality per 1000 attacked.
At all ages .	35606[‡]	28	1·7	61
0–1 . .	1155	72	6·9	96
1–2 . .	974	119	23·6	197
2–3 . .	1028	172	17·5	102
3–4 . .	1000	162	8·0	49
4–5 . .	951	170	2·6	15
All ages under 5	5108	137	11·6	85
5-10 . .	4530	62	0·7	11
10 and upwards	25968	0.75	0·0	0

The population figures for the second year of life indicate some confusion of the census figures on which they are based, and consequently throw a little doubt on the rates for the second year of life. The figures as they stand show that the main incidence of *deaths* is on the second year of life, while the main incidence of *attacks* is on the third, fourth, and fifth years of life. It follows that the *fatality* from measles is much higher in the second than in any of the three succeeding years.

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[*] *Ten Years' Compulsory Notification of Infectious Disease in Edinburgh.* By Dr. H. LITTLEJOHN, p. 138.

[†] *Supplement to the Twenty-fourth Annual Report of the Local Government Board*, p. 138.

[‡] The population figures are given, but to economize space not the number of cases and deaths. The latter can obviously be calculated, the population and the rates per 1000 being given.

The death-rates for the two *sexes* show that under 5 the death-rate from measles is higher among males (3271 in 1881–90) than among females (2992), while at the age group 5–10 the death-rate among males is 262, among females 280, and at 10–15 it is 19 and 26 per million living respectively.

The influence of *season* on the mortality from measles in London is shown in Fig. 14. There are two maxima in each year, viz., in May and June, and in November to January, the latter greater than the former. In many other towns, *e.g.*, in Paris, Berlin, and New York, the winter rise is small, the greatest incidence of the disease being in June.

Scarlet Fever. The death-rate from this disease was stated separately from that for diphtheria for the first time in 1855 in the Registrar-General's reports.

In Fig. 23 the course of the two diseases in England can be traced. As it was thought desirable to show the combined prevalence of the two diseases, a diagram drawn to scale was made for scarlet fever, and then a second diagram for diphtheria *plus* scarlet fever, the space between the two curves then representing the annual death-rate from diphtheria. The same method is adopted in Figs. 26 and 27. The death-rate from scarlet fever has varied from 1478 per million persons living in 1863, and 1446 in 1870, to 149 in 1895.

The average death-rate from scarlet fever in 1881–90 was 346 per million males and 322 per million females. At age 0-5 it was 1712 and 1627 per million living in the male and female sex respectively; at age 5–10, 758 and 765; at age 10–15, 148 and 158; at age 15–20, 43 and 40 respectively; still lower at higher ages. At all ages in the aggregate, and in children under 10 years of age, scarlatinal mortality is higher among males, but at higher ages the female rate is higher. Scarlet fever is like diphtheria, and is unlike whooping-cough, in being less fatal to infants under one year of age than to those in their second, third, fourth, or fifth years.

The rapid decline in the registered mortality from scarlet fever might be caused by diminished prevalence or diminished virulence of the disease. The question is, whether the differences shown above are due to *differences of prevalence* or *differences of case mortality* (fatality)? The *Annual Report of the Registrar-General* for 1886 gives the figures in column (*a*) of the following table, which bear on this point. They embody the facts as to the age,

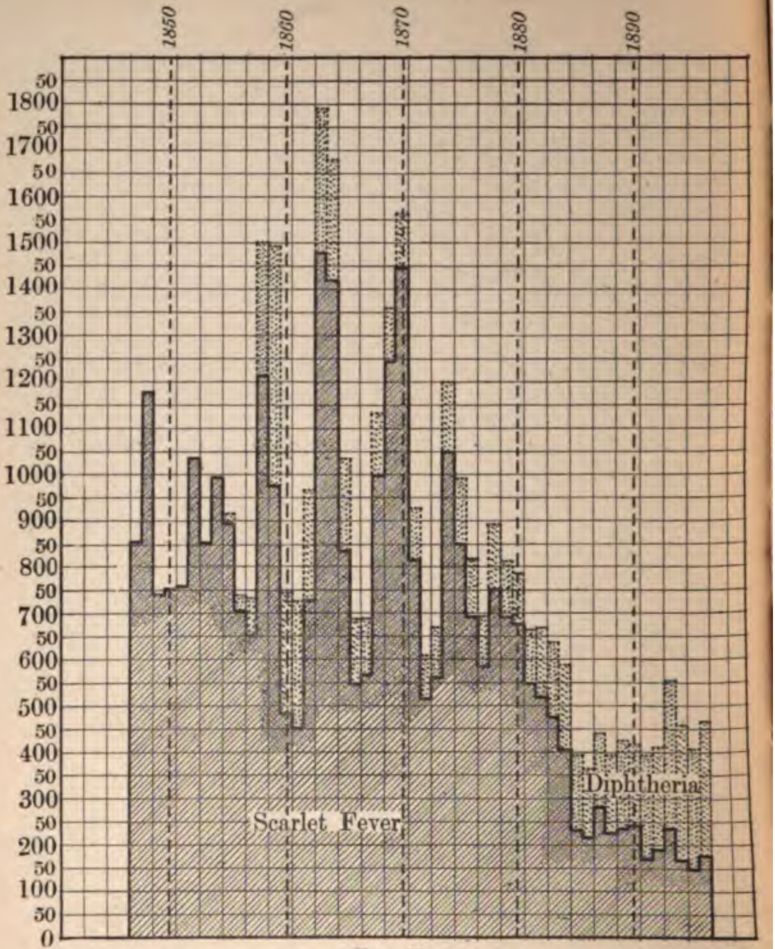

FIG. 23.

Annual Death-rate per Million of Population from Scarlet Fever and Diphtheria, 1847–96.

The dotted part of the diagram gives the Death-rate from Diphtheria, the part indicated by diagonal lines the Death-rate from Scarlet Fever, the sum of these two the combined Death-rate from Scarlet Fever *plus* Diphtheria.

sex, and result of 17,795 cases of scarlet fever in the metropolitan fever hospitals during the twelve years 1874-85, and in addition, the official reports for Christiania, in Norway, of 5000 cases which occurred there in 1870–72. It was necessary to include these, because the returns of the London hospitals did not at that time differentiate each year of the 0–5 period, during which the prevalence of scarlet fever is at its maximum. As the case mortality in Christiania for the aggregate 0–5 period was nearly the same as that of the corresponding period in London, it was fairly assumed that the rates for individual years were likewise similar.

In column (*b*) of the same table are stated the fatality at each age of 39,253 male and 42,352 female cases of scarlet fever admitted to the metropolitan hospitals in the years 1892–97.

FATALITY PER 100 CASES OF SCARLET FEVER.

Age.	1874-85.	1892-97.	1874-85.	1892-97.
	Males. (*a*)	(*b*)	Females. (*a*)	(*b*)
0–1	39·5	24·8	44·2	27·1
1–2	38·4	20·5	34·6	20·4
2–3	25·5	15·4	22·6	15·0
3–4	18·4	11·2	17·4	11·3
4–5	13·0	8·1	11·2	6·8
Total, 0-5 . .	24·1	12·8	21·7	12·0
5–10	10·6	3·1	9·7	3·0
10–15	5·6	1·3	5·3	1·1
15–20	4·0	1·5	3·4	1·5
20–25	3·9	1·2	3·2	1·7
25–35 . . .	7·5	1·7	4·3	1·3
35 and upwards .	8·5	4·9	6·5	2·6

The same figures also show that at each age and group of ages the fatality of scarlet fever has declined to a remarkable extent. As the death-rate and the fatality from scarlet fever both decline with advancing years, it is clear that the longer an attack is deferred the less likely is it to occur at all; and that even if it occur eventually, the less likely is it to end fatally.

There are no figures based on the compulsory notification of scarlet fever, twenty or thirty years ago, to enable a certain conclusion to be reached as to the question previously asked; but, on the whole, it seems clear that there has been a real "change in the constitution" of scarlet fever, and that if there is diminished prevalence of this disease it is subsidiary in importance to its diminished fatality.

Diphtheria. This disease was only separated from scarlet fever in the Registrar-General's returns in 1855, and there is little doubt that many deaths are even now returned as ulcerated throat, quinsy, croup, laryngitis, or membranous laryngitis, which should be entered as diphtheria. Elsewhere* I have discussed the influence of these changes of nomenclature, and have shown that by plotting out the annual death-rate from croup, *plus* diphtheria, we obtain approximately accurate results. It is possible that in a given diagram thus obtained, the amount of diphtheria may be understated; but the teaching of the diagram, as to which are the epidemic and which the inter-epidemic years, can be confidently accepted. It is on the position rather than on the height or depth of the crests and troughs of the epidemic waves that the main teaching of such curves depends, and these may be regarded as absolutely accurate.

The variations in the English death-rate from diphtheria since 1855 can be seen in Fig. 24. The highest was 517 per million living in 1859, and 318 in 1893; the lowest (omitting the three years 1855–57, in which there was probably still some confusion with scarlet fever) 93 in 1872. In London the highest death-rate per million living since 1859 was 761 in 1893, and the lowest 80 in 1872.

In the decennium 1881–90 the male death-rate at all ages in England and Wales averaged 158, the female 167 per million living, being 688 and 693 in the male and female sexes at ages 0–5, 373 and 474 at ages 5–10, 84 and 115 at ages 10-15, and 35 and 37 at ages 15–20.

Diphtheria agrees with scarlet fever in being less fatal to

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* *Epidemic Diphtheria: A Research on the Origin and Spread of the Disease from an International Standpoint.* Swan Sonnenschein & Co., 1898.

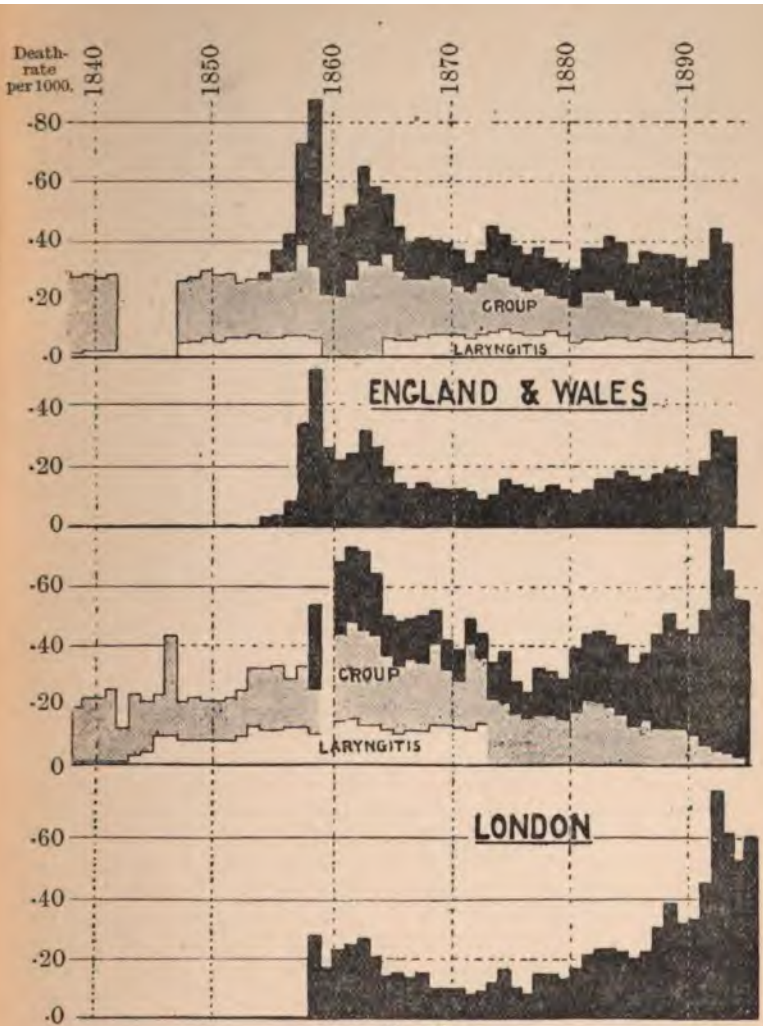

Fig. 24.

Yearly Death-rate from Diphtheria (black), Croup (mottled), and Laryngitis (clear); in (*a*) England and Wales, (*b*) London.

infants in their first year of life than in any other year of the first five.

The following table gives the experience as to the fatality from diphtheria among 11,553 male and 13,861 female patients admitted into the Metropolitan Asylums Board's Hospitals in the years 1888–97 :—

Ages.	Fatality per cent.		
	Males.	Females.	Total.
Under 1 . .	48·1	52·6	50·1
1–2 . .	50·2	50·5	50·3
2–3 . .	42·3	39·3	40·8
3–4 . .	36·7	33·9	35·3
4–5 . .	30·4	31·3	30·8
Total under 5 . .	38·9	37·2	38·0
5–10 . .	21·4	23·2	22·3
10–15 . .	8·7	8·5	8·6
15–20 . .	5·2	4·2	4·6
20–25 . .	4·7	3·6	4·0
25–35 . .	5·5	4·3	4·6
35 and upwards . .	10·9	8·5	9·4

The fatality of diphtheria has not varied so enormously as that of scarlet fever. There are no English figures stretching over a sufficient length of years to prove this statement, but the following curve derived from the experience of Copenhagen for the years 1855–94, in which city compulsory notification of infective diseases has been long established, shows that the sickness-rate and the death-rate from diphtheria closely follow each other. To bring out this point a method has been employed which is most useful in many similar inquiries. The average attack-rate (5·88 per 1000) and death-rate (·78 per 1000) for the entire period is calculated, and then the percentage deviation of each year's rate from the mean having been ascertained, these deviations are plotted out as shown in Fig. 25.

It will be observed that although the attack-rates and death-rates do not deviate greatly from one another, the fatality of the disease increased somewhat during the epidemics culminating in 1865 and in 1879, while during the epidemic culminating in 1890 the cases increased in a slightly higher proportion than the deaths.

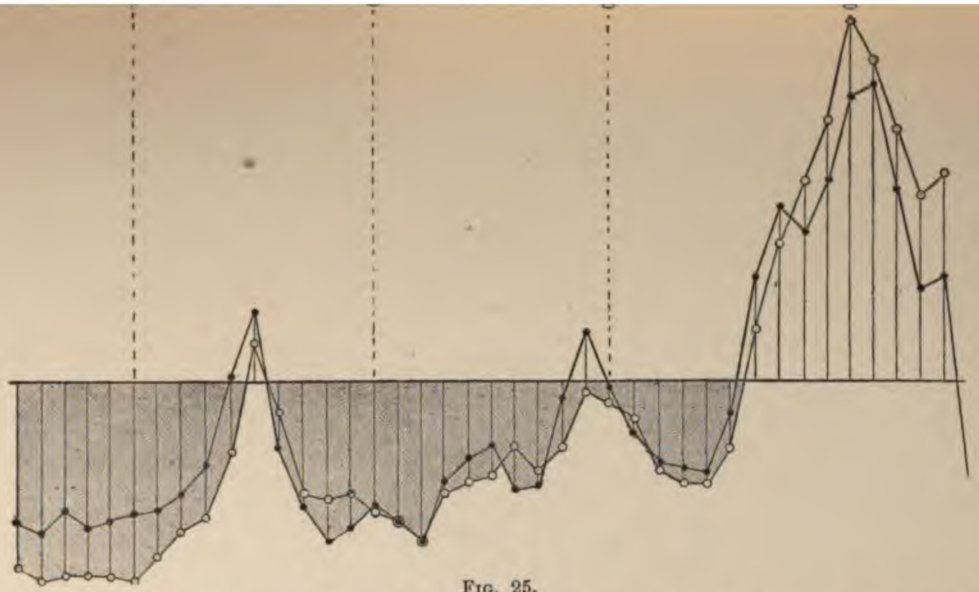

FIG. 25.

COPENHAGEN.—Annual deviation of the attack-rate (o—o—o—o) and death-rate (•—•—•—•) from the mean rate for the entire period 1855–93.

The pathogenesis and epidemicity of diphtheria are discussed in detail in the author's "Epidemic Diphtheria," to which reference must be made for further particulars.

Whooping-cough. The annual death-rate from this disease in England can be seen in Fig. 22. It has varied since 1847 between 736 per million living in 1866 and 316 in 1895. In the years 1881–90 it averaged 418 for males and 480 for females of all ages. Under 5 years of age the male death-rate per million was 3066, the female 3672; at ages 5–10 it was 100 and 155; at ages 10–15 it was 3 and 5 respectively. The death-rate per million living in 1881–90 in each of the first five years of life beginning with the first were 7085, 5490, 2168, 1186, and 641 respectively.

Fever. Under this head are included typhus fever, enteric or typhoid fever, and simple and ill-defined forms of continued fever. Typhus and typhoid fevers were definitely recognized and differentiated as separate diseases as early as 1849–51 in the writings of Jenner, and near the same time by A. P. Stewart and a few others. It was not, however, until 1869 that the three headings of typhus, enteric fever, and simple and ill-defined fever were commenced in the official returns. The course of the diseases enumerated above can be seen in Fig. 26.

In 1847 the death-rate per million from "fever" was 1807, declining to 652 in 1860, and to 895 in 1868. It is probable that in these earlier years defective diagnosis caused many erroneous entries under this head of what would now be recognized as tubercular meningitis, general tuberculosis, pneumonia, etc. This is supported by the course of the curve in Fig. 26, which shows the gradual extinction of simple and ill-defined continued fever, owing to its gradual transference to the two other headings. The rapid diminution of **typhus** is shown by clinical evidence to be real, this disease tending to become extinct in connection with improved sanitation. Thus the death-rate per million living from typhus declined from 57 in 1871–80 to 14 in 1881–90, and 4 in 1891–95.

There can be no doubt also that the reduction of **typhoid fever** is in the main a real one. In 1871–80 the death-rate from this disease was 322, in 1881–90 it was 196, and in 1891–95 it was 174 per million living. The decline at each age-period is a matter of some importance, and we therefore give the following table showing the rates and the percentage decline for each sex.

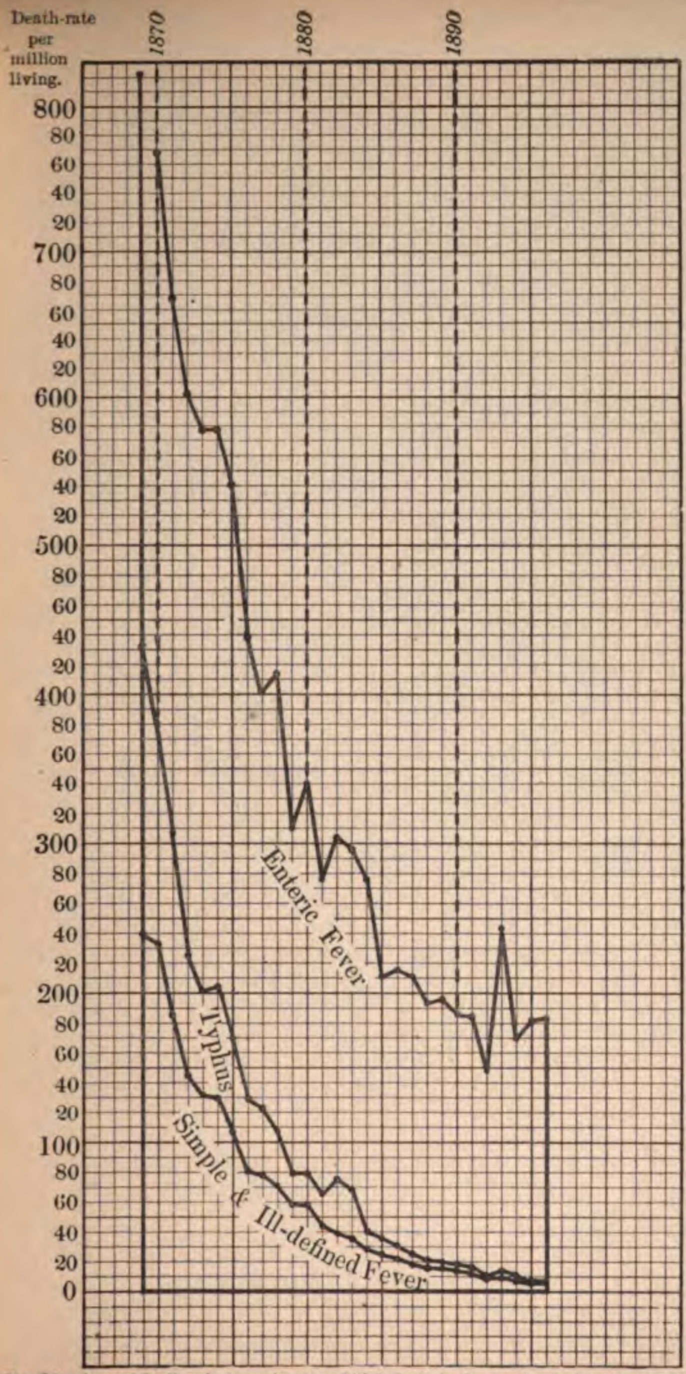

FIG. 26.—Annual death-rate from simple and ill-defined, typhus, and enteric fevers, 1869-96.

ENTERIC FEVER—ENGLAND AND WALES.

	Males.			Females.		
	Death-rate per million.		Decline per cent.	Death-rate per million.		Decline per cent.
	1871–80.	1881–90.		1871–80.	1881–90.	
All ages .	325	211	35	320	182	43
0– . .	396	131	67	404	128	68
5– . .	308	170	45	364	189	48
10– . .	273	191	30	350	225	36
15– . .	376	298	21	436	280	36
20– . .	430	336	22	334	233	30
25– . .	309	272	12	280	196	30
35– . .	258	201	22	238	164	31
45– . .	273	176	35	230	135	41
55– . .	290	165	43	247	122	50
65– . .	340	132	61	255	98	61
75 & upwards	259	71	73	187	55	71

The most striking feature of this table is, that the mortality from enteric fever has decreased much more under 10 and over 55 years of age than at the intermediate ages. The inequality of the decline of the fever-rate at different ages is probably largely owing to greater accuracy in diagnosis in regard to the very young and old, who were formerly said to die from "fever" or typhoid fever, but who are probably now grouped more accurately under other headings.

After ample allowance for this source of error, there has still been an enormous reduction of fever at all ages. Nor can the reduction of mortality be ascribed to the prevalence of a milder type of disease. This is shown by the following figures from the experience of (*a*) the London Fever Hospital (Murchison) in 1848–57, and of the Metropolitan Asylums Board's Hospitals (*b*) in 1871–97, and (*c*) in 1897.

Ages.	Fatality per 100 cases treated at each age-group.		
	(*a*) In the years 1848–57.	(*b*) In the years 1871–97 (total cases 11,148).	(*c*) In the year 1897 (total cases 664).
Under 5 . . .	12·1	12·9	7·1
5– . . .	11·3	8·9	7.7
10– . . .	12·9	13·0	9·5
15– . . .	15·5	17·5	20·8
20– . . .	20·4	20·3	18·8
25– . . .	20·5	22·9	29·9
30– . . .	25·6	24·9	34·0
35– . . .	26·4	27·2	27·3
40– . . .	26·6	24·9	25·0
45 and upwards .	19·6	33·6	23·1
All Ages . .	17·3	17·3	18·7

The decline in mortality from enteric fever must therefore be due chiefly to its diminished prevalence.

The following table shows the attack-rate and death-rate per 100,000 living from enteric fever for the entire population of London at each age-period in 1896 for the two sexes.

	Attack-rate.		Death-rate.		Fatality (Case-Mortality) per cent.	
	Males.	Females.	Males.	Females.	Males.	Females.
All ages . .	85	61	17	10	19·6	16·0
0– . . .	38	31	6	5	15·2	17·1
5– . . .	102	81	12	7	12·0	8·7
10– . . .	131	104	13	11	9·9	10·5
15– . . .	138	95	27	18	19·9	18·7
20– . . .	117	80	26	13	22·3	16·7
25– . . .	107	70	22	12	20·6	17·3
35– . . .	60	44	19	9	32·1	20·8
45– . . .	36	29	14	6	38·5	20·3
55 and upwards	21	10	·9	4	41·7	43·5

The liability to attack is seen to be greater at all ages in males than in females. The greatest liability to attack is between the tenth and twenty-fifth years of age. The fatality is higher at most ages in males than in females.

Further particulars as to the case-rate from notifiable diseases, and as to variations of fatality, will be found on p. 337.

Diarrhœa. Diarrhœa is the name of a symptom, not of a disease. It represents the residue after fatal cases, in which diarrhœa was the most prominent symptom, have been relegated to the disease which caused the diarrhœa. The Registrar-General includes dysentery under this head, but true dysentery is now unknown as a disease having its origin in this country. Many cases which were formerly entered as diarrhœa now appear as enteritis or gastro-enteritis. Thus Dr. L. Parkes (*British Medical Journal*, May 28, 1898) has shown that in London the following change in the proportion of deaths at three age-periods to total deaths from the same cause at all ages has taken place.

PERCENTAGE OF DEATHS AT THREE AGE-PERIODS TO TOTAL DEATHS.

Years.	Diarrhœa and Cholera.			Enteritis.		
	Under 1.	1 to 5.	Over 5.	Under 1.	1 to 5.	Over 5.
1861–5 . .	62	20	18	30	12	58
1896–7 . .	79	13	8	68	13	19

Similarly, if the number of deaths registered as due to enteritis be stated in relation to every 100 deaths from diarrhœa and cholera, the proportion will be seen to have increased from 11 per cent. in 1861–65 to 52 per cent. in 1896–97. It is uncertain how much of what is now returned as enteritis would have been formerly entered as diarrhœa, but the rapid increase of the death-rate from enteritis since 1877, shown in Fig. 27, is very suggestive.

The average annual death-rate from diarrhœal diseases (including cholera) was 1076 per million living in 1861–70, 935 in 1871–80, 674 in 1881–90, and 652 in 1891–95. The death-rate in 1881-90 per million living at each age-period was 4346 under 5, and 2581 at 75 and over. These diseases are, therefore,

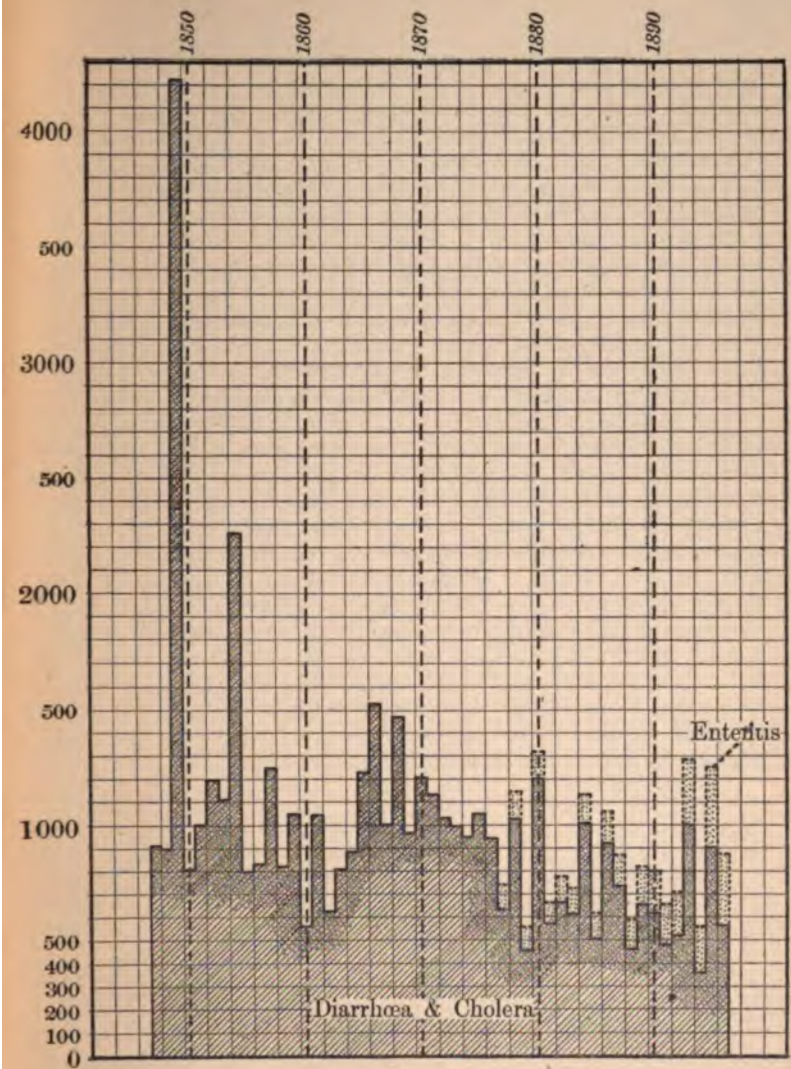

FIG. 27.

Death-rate per Million of Population from Diarrhœa and Cholera (diagonally marked) and from Enteritis (marked by dotted lines).

most fatal at the extremes of life. This is especially true for the first year of life, in which the death-rate per million living in 1881–90 was 16,044, that in the fifth year being only 145.

The connection between the temperature of the air and the prevalence of diarrhœa is shown in the annexed diagram.

Fig. 28, from an earlier edition of this work, is introduced partly for critical purposes. A more exact method and freer from fallacies would have been to work out the percentage deviation of each week's temperature during 1887 from the corresponding week's temperature for a series of years, and similarly to work out the percentage deviation of each week's diarrhœal death-rate from the corresponding average weekly death-rate in a series of years, and then to plot out the two series of figures (which would now be on a corresponding scale) in a diagram.

Diarrhœa being eminently an infantile disease, so far, at least, as it is fatal, and in fact being almost synonymous with epidemic diarrhœa, it would be preferable to state it in terms of the number of births (p. 188). By this means, a portion of the discrepancy in the death-rate from diarrhœa in great towns is removed. Considerable differences still remain when this correction has been applied. These differences are partly due to the varying presence of insanitary conditions, especially those connected with pollution of the soil and the atmosphere with excremental matter; but social reasons also have undoubtedly a great influence, as the occupation of the mothers, the varying amount of feeding by hand, etc. The prevalence of diarrhœa is a matter of great importance, and ought to receive further elaborate and combined investigation by skilled observers.

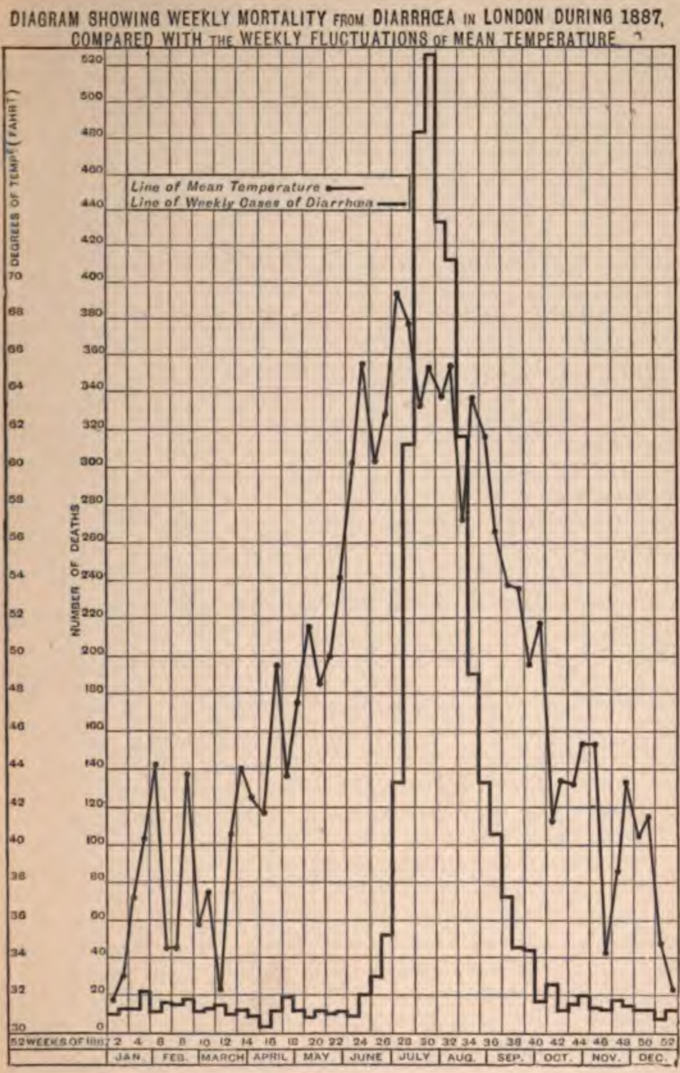
DIAGRAM SHOWING WEEKLY MORTALITY FROM DIARRHŒA IN LONDON DURING 1887,
COMPARED WITH THE WEEKLY FLUCTUATIONS OF MEAN TEMPERATURE.
DEGREES OF TEMPᴱ (FAHRT)
NUMBER OF DEATHS
Line of Mean Temperature
Line of Weekly Cases of Diarrhœa
70
68
66
64
62
60
58
56
54
52
50
48
46
44
42
40
38
36
34
32
30
520
500
480
460
440
420
400
380
360
340
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
52 WEEKS OF 1887
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52
JAN.
FEB.
MARCH
APRIL
MAY
JUNE
JULY
AUG.
SEP.
OCT.
NOV.
DEC.

FIG. 28.

CHAPTER XIX.

SMALL-POX AND VACCINATION.

PROBABLY no department of vital statistics is so important as that which deals with small-pox and vaccination. As certainly, in no department of medicine has so large an appeal to figures been made, and in none have the deductions from figures been so contradictory, in a large measure owing to the intense mental bias with which this subject has been taken up by those whose chief anxiety appears to be to mould the figures so as to fit in with their preconceived prejudices. There has not only been incompetence and ignorance on the part of many anti-vaccinators who have dealt with vaccination and small-pox, but in some cases culpable misconduct in dealing with statistics.

The Royal Commission on Vaccination have issued six enormous volumes of evidence and nine further volumes of reports of special inquiries made on behalf of the Commission. The final report of the Royal Commission, published in August, 1896,* comprises an excellent summary of the main facts and arguments relating to vaccination from every standpoint, and is essential for all who wish to obtain a grasp of the subject. The same volume contains the dissent of Dr. Collins and Mr. Picton, two members of the Commission, from the report, embracing practically everything that can be said on the anti-vaccination side. The review of the dissentients' statement by Dr. McVail† exposes in a masterly fashion the errors into which Messrs. Collins and Picton had fallen. The study of the preceding volumes will enable the intelligent reader to expose with ease the fallacies contained in the anti-vaccination pamphlets by Russell, Paul, and others.

It is impossible here to more than summarize some of the chief facts of the subject and to indicate the chief errors, which have an incidental value as instances of statistical fallacies.

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* Eyre and Spottiswoode, 1*s.* 10*d.*

† P. S. King and Son.

One of the chief errors has been to give average death-rates for small-pox for series of years. The dangers of such average death-rates have been already emphasized (see p. 191). A glance at Fig. 29 will show how very easy it would be, especially in its earlier portion, to arrange the death-rates in groups of years, so that either a reduction or an increase of small-pox mortality could be displayed in contrasting two contiguous periods.

The death-rate from small-pox per million inhabitants in England has varied since 1847 from 1 in 1889–90 to 1012 in 1871. The epidemic peaks since 1847 have occurred in the following years: 1847 (507), 1852 (401), 1858 (329), 1864 (364), 1871 (1012), 1877 (173), 1881 (119), 1885 (104), 1888 (36), 1893 (49). In London the death-rate from small-pox has varied since 1848 between 0 in 1889 and 7912 in 1871. The epidemic peaks have occurred in the following years: 1848 (1620), 1852 (1159), 1855 (1039), 1859 (1158), 1863 (1996), 1866 (1391), 1871 (7912), 1877 (2551), 1881 (2367), 1885 (1419), 1893 (206).

During 1896, 541 deaths in England and Wales were referred to small-pox, corresponding to a rate of 1·8 per million, compared with rates of 7, 27, and 49 in the three preceding years. Of the total 541 deaths from small-pox, 443 occurred in the registration district of Gloucester. During the first half of 1896 the mortality of this city was increased, on account of small-pox alone, by 143 per cent.

Although average death-rates for groups of years should not be considered alone, they may serve to indicate, without fallacy, if due precautions are taken, the trend of a particular disease, and for this purpose the following figures are useful:—

DEATH-RATE PER MILLION FROM SMALL-POX IN ENGLAND AND WALES.

Period.	Persons.	Males.	Females.	Remarks.
1861–70 .	160	179	142	two epidemics.
1871–80 .	234	265	205	two epidemics.
1881–90 .	45	52	38	two epidemics.
1891–95 .	20	—	—	one small epidemic.

The decrease in the death-rate from small-pox has until recent years been much greater in the provinces than in London, probably owing rather to the more frequent opportunities of infection in the latter than to any other cause. Thus in 1838–42

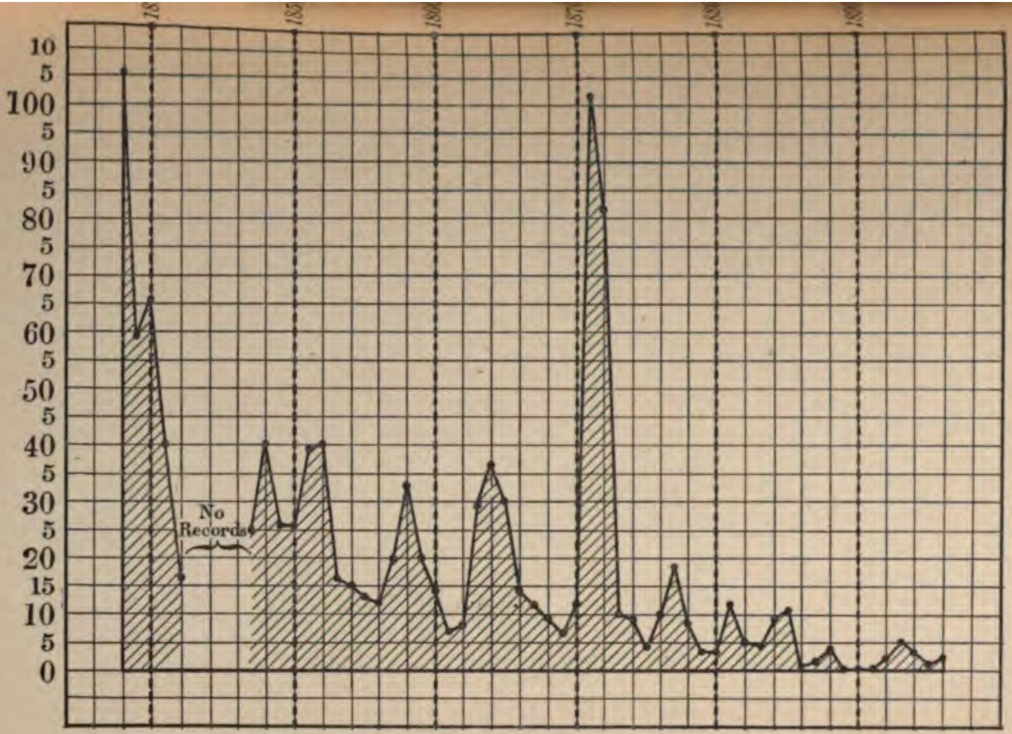

FIG. 29.

Annual Death-rate per 100,000 living from Small-pox in England and Wales.

the death-rates per million living in England as a whole and in London respectively were 755 and 547, while in 1880-84 they were 244 and 34. In 1891–95 the death-rate from small-pox in London has only averaged 19 per million, as compared with 20 in the whole of England. There can be little doubt that the greatly improved isolation accommodation for small-pox patients, in hospitals remote from centres of population, is chiefly responsible for this great improvement in the metropolis. The efficiency of hospital isolation as a means of preventing epidemic small-pox in a community of which the largest proportion has been vaccinated is one thing; it is quite another thing in an unvaccinated community. In view of the extreme infectiousness of the disease, it is more than doubtful if isolation and the collated measures would suffice to prevent epidemic small-pox in the absence of vaccination.

Small-pox in the Pre-registration Period. Fig. 29 shows that there has been a decrease of small-pox mortality during the period for which there are official records in England. A study of small-pox, which is confined to these sixty years, does not, however, give an adequate conception of the remarkable fall in small-pox mortality which has occurred. The work of vaccination in reducing small-pox was in a large measure accomplished by the middle of the nineteenth century, and since that time there has been much less scope for diminution. This will be clearly seen from the diagram relating to London, which faces p. 6 of Dr. McVail's *Vaccination Vindicated* (Cassell and Co., 1887), which, although published before the issue of the report of the Royal Commission on Vaccination, still remains an authoritative book on the subject. Small-pox reached its highest point in 1796 (two years before the date of Jenner's "Inquiry"), when 18½ deaths out of every 100 total deaths were caused by small-pox. In the pre-vaccination period small-pox was nine times as fatal as measles and seven and a half times as fatal as whooping-cough (McVail). Under vaccination it has sunk to an insignificant position when compared with these diseases.

The Epidemic of Small-pox of 1870–73. Dr. Guy applied the term epidemic to any outbreak causing one-tenth or more of the total deaths from all causes in any year. He found that in London there were ten such epidemics of small-pox in forty-eight years of the seventeenth century, twenty-nine in the eighteenth century, and none in the nineteenth century. If the standard be reduced to 7½ per cent. of the total deaths, then fourteen epidemics occurred in the seventeenth century, sixty in the eighteenth, four in the nineteenth (McVail, *op. cit.*, p. 44). The above figures relate to London. The worst year under obligatory vaccination in London was 1871, in which barely 4½ per cent. of the total deaths were due to small-pox, a proportion which was exceeded in the eighteenth century ninety-three times.

The 1870–73 epidemic, notwithstanding its comparatively small magnitude, has been frequently employed to show the inutility of vaccination. From 1847 to 1853 vaccination was optional; between 1854 and 1871 it was obligatory, but not efficiently enforced; from 1872 onwards it was obligatory, and more efficiently enforced by vaccination officers until recent years, in which the enforcement has become gradually relaxed in many districts. If we waive for the moment our objection to death-rates for groups of years, and contrast the death-rate in the five years 1865–70 with those in the two 5-year periods 1871–75 and 1876–80 (1871 being the maximum epidemic year, and the year preceding that in which the more rigid Vaccination Act came into operation), we find that in the former period the death-rate from small-pox was 105, and in the latter periods 411 and 78 per million persons in England and Wales. The Vaccination Act in question was directed towards securing infantile vaccination. It will be interesting, therefore, to observe the distribution of the above death-rates according to age. This is shown in the following table:—

Death-rate from Small-pox per million living.	1865–70.	1871–75.	1876–80.
At ages under 5 .	413	937	145
5–10 years . .	97	524	73
10–15 ,, . .	32	234	52
15–25 ,, . .	73	428	89
25–45 ,, . .	60	351	82
45 years and upwards	25	136	34
At all ages* . .	105	411	78

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* In the above table the average death-rates have, for the sake of convenience, been obtained by the less accurate method of adding together the death-rates given on p. 155 of the final report of the Royal Commission on

It will be seen that in the period 1871–75, during most of which small-pox was epidemic, a period including at least one year in which vaccination was not efficiently enforced, the death-rate under 5 years of age was only two and a quarter times as high as in 1865–70 (this period also includes one minor epidemic year), while the death-rate at other age-periods was five to seven times as high as that in the earlier years. In the next period (1876–80) no epidemic occurred, and the death-rate under 5 was only about one-third the corresponding death-rate in 1865–70, while at ages over 10 it was slightly higher than in the earlier period. The critical age is evidently 0–5; but to bring out the real facts in connection with this age-period, it would be necessary to classify the deaths according as they occurred in vaccinated or unvaccinated children, which the above figures do not attempt. Furthermore, if we trace the period of compulsorily enforced vaccination from 1872, it is obvious that only those born after 1871 can be affected by this compulsion. Hence not only does the age-period 0–5 require to be further subdivided, but the deaths at ages over 5 are outside the scope of compulsory vaccination. These are the ages which show the greatest increase of small-pox, during 1871–75. The significance of these facts will be made clearer by a study of Figs. 30 and 31.

Small-pox in other Countries. In Sweden complete records of mortality from 1774 onwards are available. It is impracticable to reproduce these in full here,* but the main points may be gathered from the following figures:—

SWEDEN.—(*a*) *Before vaccination* (1774–1800) highest death-rate from small-pox was 7227 per million inhabitants in 1779; lowest was 311 in 1786; average of 27 years = 2008.

(*b*) *Permissive vaccination* (1801–1815): highest death-rate, 2570 in 1801; lowest, 121 in 1814; average of 15 years = 631.

(*c*) *Compulsory vaccination* (1816–1885): highest death-rate, 935 in 1874; lowest, 0·5 in 1846; average of 70 years = 173.

In Prussia the death-rates from small-pox for the period 1816–82 were as follows:—

Vaccination in quinquennial groups, and then dividing by 5, instead of by the more accurate method of adding together separately the deaths and the population for each five years, and then calculating the death-rate. The error is a very small one.

* See *Vaccination and Small-pox*. By Dr. E. J. EDWARDES. Churchill, 1892.

PRUSSIA.—*Death-rates per* 100,000 *living.*
1816–30.—45, 27, 29, 20, 10, 17, 20, 19, 14, 15, 14, 25, 19, 19, 24.
1831–50.—11, 30, 60, 48, 27, 18, 15, 16, 14, 16, 14, 22, 28, 27, 15, 15, 9, 13, 10, 15.
1851–70.—12, 18, 39, 43, 9, 7, 13, 26, 19, 18, 30, 21, 33, 46, 43, 62, 43, 18, 19, 17.
1871–72.—243, 262.
1873–74.—35, 9.

Revaccination of general population in school-age made compulsory in 1874.

1875–82.—3·6, 3·1, 0·3, 0·7, 1·2, 2·9, 3·6, 3·6.
1883–86.—4·0, 1·5, 1·4, 0·5.

The following figures for Austria are important, as apart from the enforcement of the vaccination law of 1874 in Prussia, all other conditions appear to be the same in the two countries. (See Dr. A. F. Hopkirk's evidence before the Royal Commission.)

AUSTRIA.—*Death-rates per* 100,000 *living.*
1842–44.—20, 16, 13.
1845–46.—Data are wanting.
1847–71.—14, 18, 21, 15, 26, 25, 51, 59, 62, 31, 36, 56, 44, 23, 22, 31, 53, 84, 45, 36, 47, 33, 35, 30, 39.
1872–74.—189, 323, 178.
1875–81.—57, 39, 53, 60, 50, 64, 82.

It would be easy to multiply instances of comparisons between comparatively well-vaccinated and comparatively badly-vaccinated communities, but the following figures dealing with the epidemic years centring about the year 1871 must suffice.*

Small-pox. *Deaths per million living in the two worst years of the epidemic* 1870–74 (Körösi). Comparatively badly-vaccinated countries: Prussia (1871–2), 5060; Holland (1870–2), 5490; Austria (1872–4), 6180. Comparatively well-vaccinated countries: Scotland (1871–2), 1470; England (1871–2), 1830.

Further instances may be obtained in the evidence given before the Royal Commission on Vaccination.

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* From KÖRÖSI'S *Kritik der Vaccinations statistik und neue Beiträge zur Frage des Impfschutzes.* Berlin, 1890.

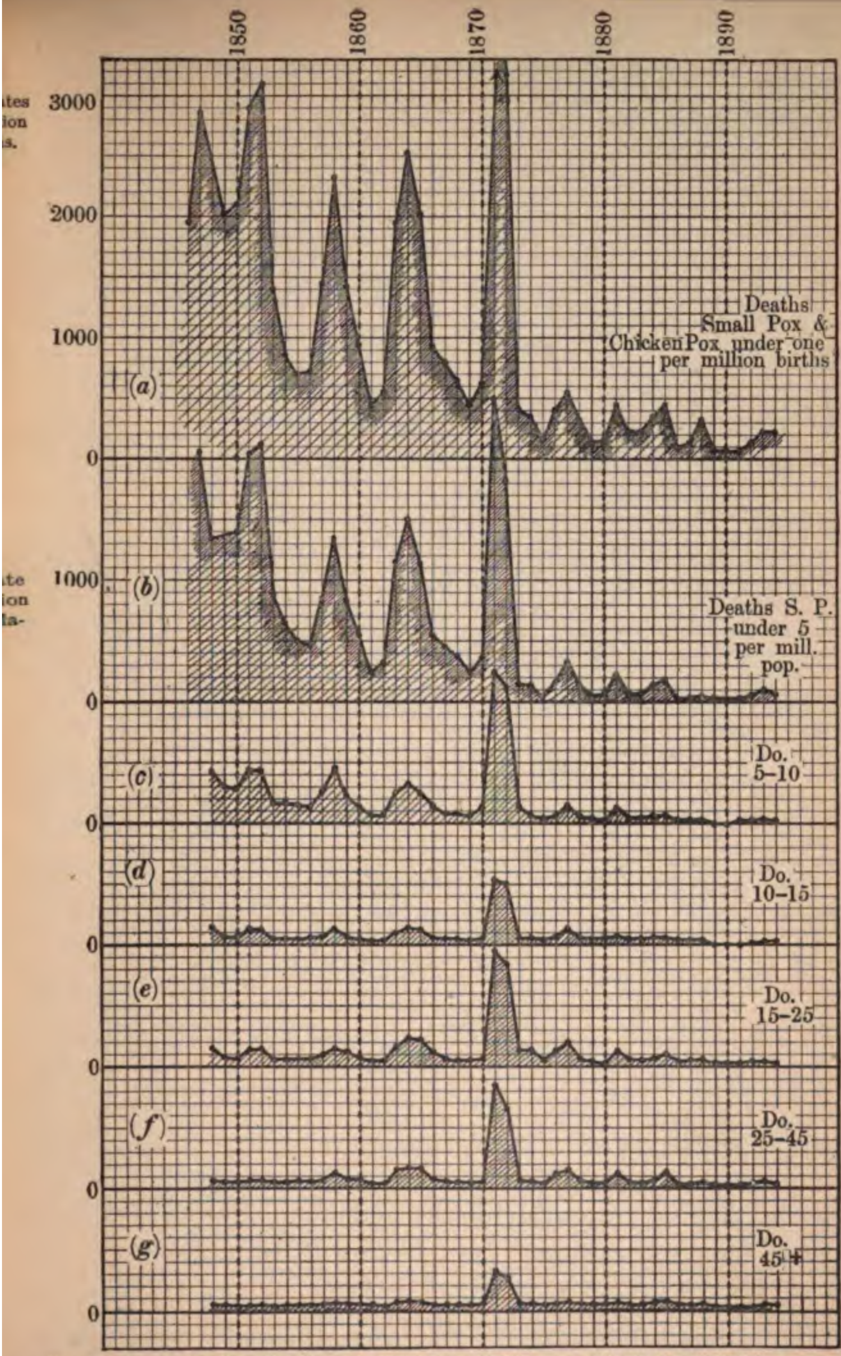

Fig. 30.—Death-rates from Small-pox, in England and Wales, according to Age (1847–94).
th-rates from Small-pox and Chicken-pox under One Year of Age per Million Births. (b) Deaths from Sma
ox at all *Ages under Five per Million* living at these Ages. (c) Ditto, Aged 5–10. (d) Ditto, Aged 1
) *Ditto, Aged 15–25.* (*f*) *Ditto, Aged 25–45.* (*g*) Ditto, Aged 45 and over.

Age-incidence of Small-pox Mortality. Fig. 29 shows the variations in the death-rate from small-pox at all ages together since 1847. In Fig. 30 the same facts are shown for different age-periods, and it is particularly instructive to note the differences in the decline of the small-pox death-rate at different ages.

In the uppermost curve (*a*) of Fig. 30 the deaths from small-pox and chicken-pox together, under one year of age, are plotted out as a rate per 1000 births in each year.* The two have been stated together because of the alleged confusion between these two diseases in the returns for earlier years. The inclusion of chicken-pox probably does not materially affect the height or fluctuations of the curve, but Dr. McVail's remarks, quoted below, should be noted.

The statistics embodied in the uppermost curve are derived from Dr. Ogle's table on p. 646 of the *Sixth Report of the Royal Commission on Vaccination;* those in the lower curves from the table on p. 155 of the *Final Report of the Royal Commission on Vaccination.*

Subject to intercurrent epidemics, this curve shows a steady decline of small-pox mortality in infants, interrupted by the epidemic of small-pox in 1870–71, an interruption which we have already noted is shared to a much greater extent by every other age of life.

At all ages under 5, and at ages between 5 and 10 (Fig. 30, *b* and *c*), there has been a similar and equally marked decline of mortality from small-pox, while at the higher ages there is comparatively little alteration.

Dr. McVail points out, however, that the number of deaths registered as being due to chicken-pox in years in which small-pox is not epidemic, may be nearly as great as the small-pox deaths. In epidemic years it might reasonably be expected that if these deaths were really due to small-pox they would probably be greater in number than in non-epidemic years, which is not the case. The above lumping together of deaths from small-pox and from chicken-pox would therefore lead to some error as to age-incidence of small-pox deaths in infancy, when these are stated as a percentage of total small-pox deaths at all ages. Hence in Fig. 31 (*a*), the infantile small-pox deaths do not include chicken-pox deaths. The error is so small, when

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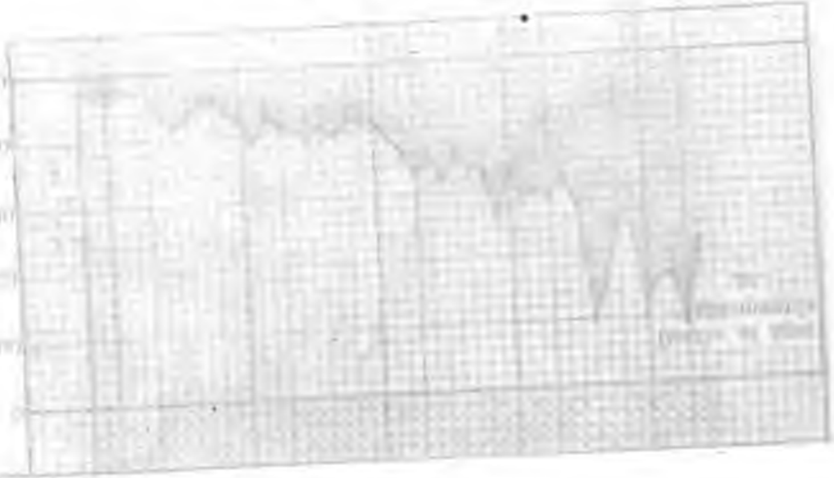
* The deaths under one year of age from small-pox and from chicken-pox are classed together in the above diagram, on the supposition that a considerable proportion of the deaths registered as due to chicken-pox were really due to small-pox.



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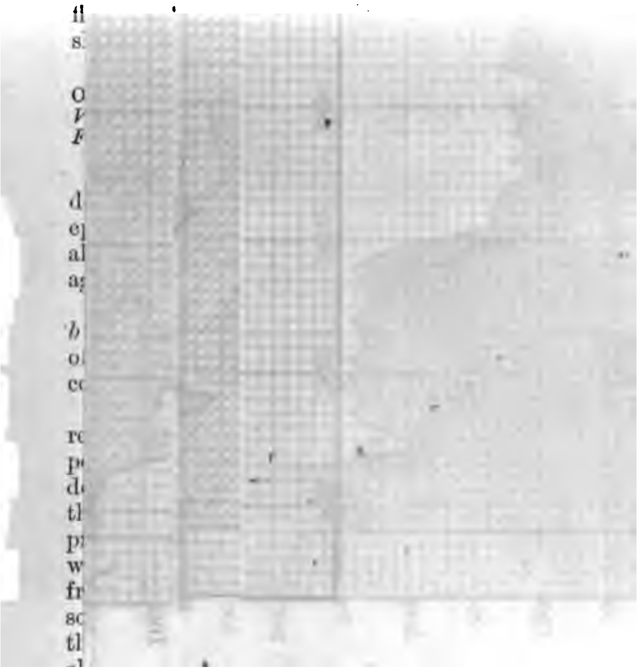

the infantile deaths are stated in terms of the infantile population, that Dr. Ogle's figures have been given in Fig. 30 (*a*) in order to avoid laborious re-calculations. If the subject were left at this point, a most important lesson would escape attention. This can only be brought out by considering what proportion of the total deaths from small-pox have occurred at different ages in successive years. This is shown in Fig. 31.

The statistics embodied in Fig. 31 are derived from the table on p. 154 of the *Final Report of the Royal Commission on Vaccination.*

Fig. 31 brings out in a remarkable manner the altered age-incidence of small-pox mortality. Thus, in the uppermost curve (*a*) of this figure, we note that small-pox mortality in infancy, prior to 1870, nearly always formed 20 per cent. or more of the total mortality from this disease; between 1870 and 1890 the small-pox mortality at this age did not greatly exceed 10 per cent. of the total, but since 1890 it has again begun to form an increasing proportion of the mortality at all ages. At ages 1–5 (Fig. 31, *b*), the change is even more remarkable. Before 1870 the small-pox deaths between 1 and 5 years of age nearly always exceeded 30 per cent. of the total; since 1870 they have varied between 5 and 14 per cent. of the total; while since 1890 they have formed, as under 1 year of age, an increasing proportion of the total small-pox deaths. At ages 5–10 (Fig. 31, *c*), a similar but less extensive alteration has occurred. Between 10 and 15 (Fig. 31, *d*) there is some proportional increase. At ages 15–25 (Fig. 31, *e*), the increase since 1870 is very marked, while at ages over 25 the same phenomenon is visible.

How is this alteration of age-incidence of small-pox mortality to be explained? It is plain that some influence or influences have been at work (*a*) making small-pox much less fatal in England and Wales; (*b*) that the reduction in the death-rate from small-pox has been greatest under ten years of age; (*c*) that of the reduced death-rate from small-pox which has occurred in recent years, a much higher proportion has fallen in adult life, so much so that the age-incidence of small-pox mortality may be described as almost exactly inverted; (*d*) that in the last few years the curves show a tendency for small-pox to revert towards its original type as a disease chiefly fatal among children.

The explanations given of this altered age-incidence are—

(1) That it has been effected by the more or less general vaccination of the community.

(2) That it is caused by sanitary improvements, which operate more effectually upon young children than upon others.

(3) That it is explicable by the fact that epidemics of small-pox now occur at longer intervals than formerly when measures of isolation were unknown, and when inoculation was generally practised.

(1) If the supposition that the great fall in small-pox mortality is due to vaccination is correct, why has the mortality from small-pox among those beyond 15 years of age not shared in this decrease? To begin with, the protection afforded by vaccination is *less perfect* than that afforded by a previous attack of small-pox; and in the next place it is *less permanent*. Its protective influence steadily diminishes, while that of an attack of small-pox remains almost unaltered. Starting with these facts, the change in the age-incidence of small-pox is explained as follows:—

Before the introduction of vaccination but few persons escaped having small-pox at some period of their lives, and the great majority had it when young. Of these a large proportion died, making the small-pox mortality for the early age-periods high; but those who survived, forming a large proportion of the population at the later age-periods, and being permanently protected by an attack of small-pox, made the small-pox death-rate of the later ages a low one. With vaccination the susceptibility of young and old was altered, and in large measure inverted, with a corresponding effect on the small-pox mortality at different ages.

The changes in the age-incidence of small-pox are so great as entirely to preclude any possibility of referring them to errors of registration or fluctuations due to chance. The most natural and probable explanation of them is that vaccination confers an immunity from small-pox in the earlier years of life, which, however, is less complete and permanent than the immunity conferred by an attack of small-pox, thus explaining the fact that the higher ages have not shared in the improvement, and at the same time indicating the necessity for re-vaccination at the age of puberty.

(2) We must consider the hypothesis which maintains that the decline in small-pox mortality is due, not to vaccination, but to general improvement in the sanitary condition of the community. To begin with, no scrap of evidence is forthcoming, which shows any connection between bad drainage or other sanitary defects and small-pox. In this respect it is like measles and whooping-cough, which remain as prevalent as formerly, despite the immense strides which have been made in sanitary improvements. In

denying any connection between insanitation and small-pox, an exception must be made in respect of overcrowding. Like other infectious diseases, small-pox is most easily spread when the most frequent opportunities exist for personal intercourse. It is therefore most often met with, and greater in amount, in busy centres of population than in scattered rural districts. The most noteworthy feature of the last forty years has been the rapidly increasing urbanization of the population, and the immense extension of travelling conveniences. And yet, notwithstanding the increase of these adverse influences, the small-pox death-rate has rapidly declined.

(3) Dr. McVail, in his evidence before the Royal Commission, pointed out that the age-incidence of deaths from small-pox would vary according to the interval between epidemics. Thus, in Kilmarnock and Geneva, during last century epidemics came every four or five years, and nine-tenths of the deaths from small-pox occurred in children under 5 years of age. In Boston, U.S.A., epidemics came about every twelve years, and the average at death would therefore be higher than the above. *For the unvaccinated* the periodicity of the disease governs the age-incidence, with the limitation to be immediately noted; *for the vaccinated* this is not so. The limitation referred to is that furnished by the fact that the protected state of the vaccinated diminishes the chances of infection, even for the unvaccinated, and therefore diminishes the number of epidemics. Hence the age-incidence of deaths from small-pox among the unvaccinated will be higher in a generally vaccinated than in a generally unvaccinated community. Thus in the years 1881–87, of 3099 unvaccinated deaths from small-pox only 39 per cent. were under 5 years of age, as compared with about 80 per cent. in the last century (McVail). At the same time, of one hundred vaccinated deaths from small-pox only nine were under 5 years of age.

As regards inoculation, it is only necessary to examine Figure 29, noting at the same time the historical fact that inoculation of small-pox was made illegal in the year 1840.*

As regards isolation of small-pox patients, this has undoubtedly contributed to minimize outbreaks; such isolation has only been systematically applied in recent years, and in a limited number of districts. It does not, furthermore, explain why in recent years there is a distinct tendency for small-pox to become again, to a greater extent, a disease of early life.

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* The *Report of the Royal Commission on Vaccination* (p. 17) states, "it seems probable that inoculation did not tend to increase the *prevalence* of small-pox. In London, during the eighteenth century, little or no inoculation was practised until after 1740, but it rapidly increased after that date, and yet small-pox showed as marked an increase in the first half of the century as in the second.

The recent neglect of vaccination in large communities is at least a feasible explanation of this latter fact: and if we study Figures 30 and 31 in view of the facts that—

(1) From 1847–53 inclusive gratuitous vaccination was provided, but recourse to it was purely optional;
(2) From 1854–71 vaccination was obligatory, but there were no effectual means to enforce the obligation thus instituted;
(3) From 1871 onwards, Boards of Guardians were obliged to appoint public vaccination officers in each district, and vaccination was more effectively enforced;*
(4) In more recent years, especially since 1890, there has been increasing neglect of vaccination;

the conviction is forced upon the mind that the reduction in small-pox mortality, and the alteration in age-incidence of the residual mortality, are related to each other as cause and effect.

Altered Age-incidence of other Diseases. An attempt was made in the Dissent of Dr. Collins and Mr. Picton† to show that other diseases show changes in age-incidence analogous to those in small-pox.

Typhus and Typhoid Fever have been instanced. The difficulties of diagnosis render this comparison largely nugatory. It is well known that formerly many deaths among the very young were entered as caused by "fever," which would now be returned under their proper headings in connection with cerebral and respiratory affections, and especially with tuberculosis (pp. 200 and 239). The percentages of deaths under 5 to deaths at all ages for four successive quinquennia are as follows:—

	1871–75.	1876–80.	1881–85.	1886–90.
Typhus	6·4	6·1	3·5	3·4
Typhoid	17·4	16·0	9·3	7·5

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* It is probable that the law of 1871 made more difference in the vaccination age than in the number vaccinated. It caused vaccination in the early months of life to be much more regularly adhered to (McVail).

† *Op. cit.*, p. 184 *et seq.*

It will be noted that a sudden change in age-incidence occurred in 1881–85, and that since that time no further great change has occurred. Compare this with the continuing alteration in age-incidence shown in Fig. 31. It must be noted furthermore that fatal small-pox, unlike "fever," is not a disease in which difficulties of diagnosis can occur, except with the greatest rarity. The first three columns of the following table are taken from pp. cxii.–cxiii. of the *Supplement to the Forty-fifth Annual Report of the Registrar-General.* The last column has been calculated by the author.

The death-rate from each cause is taken as unity, and then the death-rate at ages under 5 is stated proportionately to this.

PROPORTIONAL MORTALITY UNDER 5 YEARS OF AGE.
(Mortality at all Ages = 1.)

	1851–60.	1861–70.	1871–80.	1881–90.
From all Causes	3·0	3·0	2·9	3·0
,, Measles	6·8	6·8	6·8	7·1
,, Scarlet Fever . . .	4·7	4·7	4·8	5·0
,, Diphtheria . . .	4·0	4·1	3·9	4·2
,, Whooping-cough . .	7·2	7·2	7·1	7·5
,, Diarrhœa	4·9	5·6	6·1	6·4
,, Fevers (including typhus, typhoid, and ill-defined)	1·5	1·4	1·3	0·8
,, Small-pox . . .	4·7	4·0	2·2	1·8

In most of the above diseases, the proportion of deaths under 5 has remained stationary or slightly increased, with the exception of "fever" (a doubtful whole, in which immense difficulties of diagnosis are involved), the proportion of which under 5 has declined from 1·5 to 0·8; and small-pox (a well-marked and easily recognizable disease in its fatal form), in which the proportion has declined from 4·7 to 1·8.

It must be remembered that the comparison in the above tables is between periods of less and of more vaccination, and not between periods of vaccination and no vaccination. This makes comparison between small-pox reduction and "fever" reduction decidedly unfair. The causes of reduction of typhus and typhoid fever are recent causes, and almost their *whole effect* is seen in recent years; whereas small-pox had already shrunk from a giant to a dwarf before the years of the above comparison.

Influenza has also been instanced, reference being made by Dr. Collins and Mr. Picton to the *Fifty-fourth Report of the Registrar-General*, in which he states that "the epidemic of 1890–91 was distinguished from the equally fatal epidemic of 1847–8 by the greater comparative severity with which it attacked persons of middle age."

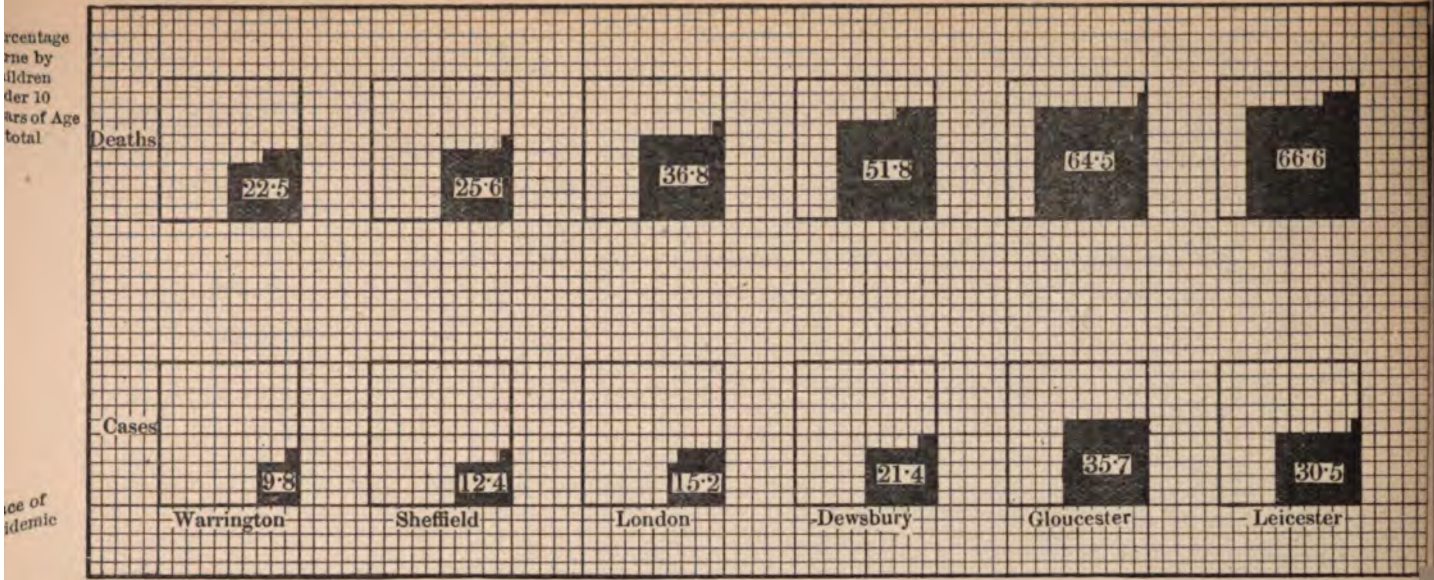
This comparison, only embodying two years of the recent epidemic of influenza, cannot be regarded as trustworthy. The question of diagnosis arises as in the case of "fever." In influenza there is no exanthem, and it is highly probable that in the two epidemics the proportion of cases in which the primary cause of death—influenza—or only the secondary cause, such as pneumonia, etc., was inserted in the death-certificate would vary considerably. Taking, however, the death-rates as they appear in Table G, p. xx. of the above report, I have calculated the percentage of total deaths from influenza at all ages which have occurred at each age-period, the result being shown in the following table :—

PERCENTAGE OF TOTAL DEATHS FROM INFLUENZA AT ALL AGES OCCURRING AT EACH AGE-PERIOD.

Age-period.	1847–48.	1890–91.
Under 5	3·3	2·3
5–	0·4	0·4
10–	0·2	0·3
15–	0·2	0·8
20–	0·4	1·5
25–	0·6	2·7
35–	1·3	4·6
45–	3·8	8.4
55–	11·2	15·4
65–	25·8	26·0
75–	52·8	37·6
	100·0	100·0

A comparison of this table with the results indicated in Fig. 31, shows that the attempt to prove any analogy between the two is entirely futile.

Local Variations of Age-incidence of Small-pox. The report of the Royal Commission embodies a series of facts on this point, which are summarized in Fig. 32.



te of idemic	1892–3	1887–8	1892–3	1891–2	1895–6	1892–3
mensions Epidemic { Cases . .	661	4677	2353	1012	1979	357
Deaths . .	62	496	182	110	434	21

FIG. 32.

The relative proportion of deaths from small-pox under 10 years of age to total deaths from small-pox at all ages, varied in recent epidemics of this disease which were specially investigated on behalf of the Commission, from 22·5 in Warrington to 66·6 per cent. in Leicester. The relative proportion of cases under 10 years of age varied from 9·8 per cent. of the total number at all ages in Warrington to 35·7 per cent. in Gloucester. In conjunction with these variations of age-incidence of small-pox we have the facts that in Warrington and Sheffield the percentage of the population unvaccinated was very small. In the ten years 1883–92 the returns for the union of Warrington (which includes the borough) show that 4·8 per cent. of the births were not accounted for. In London, in 1883, the percentage of births left unaccounted for was 6·5, gradually increasing to 16·4 per cent. in 1891. In Dewsbury the number not accounted for increased from 12·6 per cent. in 1882 to 37·7 per cent. in 1892. In Leicester the percentage unaccounted for increased from 43·8 in 1883 to 80·1 in 1892; in Gloucester from 10·6 in 1885 to 85·1 in 1894.

The Royal Commission's report lays stress on the facts briefly summarized above, pointing out that they are not open to the same chance of error as is involved in a comparison of the mortality among persons said to be vaccinated or unvaccinated.

It is contended on the other side that the proportion of attacks occurring among children will depend upon the incidence of the infection. Thus "in Warrington the small-pox was mainly spread in forges near the hospital, and there were 596 sufferers over 10 to 65 children under 10. In Leicester, on the other hand, children were specially attacked owing to the proximity of the small-pox hospital to the scarlet fever wards." (It should be noted, however, that in the percentage of deaths in Leicester under 10, three deaths occurring in the scarlet fever wards have been omitted, thus reducing the proportion from 71·4 to 66·6.) This contention might be accepted if, on investigation, it were found that the outbreak was confined to the particular section of the population among which it began. As the Leicester outbreak was speedily stamped out, such an assertion may be partially true for its small-pox in 1892–3. It is absurd, however, to assume that this explanation carries any weight in an instance like Gloucester, whose small-pox epidemic only ceased when all the susceptible persons in the city had been attacked. Furthermore, the facts that in Warrington large ironworks were selected for severe attack by small-pox, and in Gloucester one or two elementary schools suffered severely, is evidence of the value of primary vaccination, which was enforced in Warrington and not in Gloucester. In Leicester small-pox attacked the scarlet fever hospital, the scarlatinal occupants of which were sent home, where scarlet fever became widely epidemic.

It is further contended * that the age-incidence argument is full of danger, as it ignores the "true fatality results." These, it is asserted, can be tested by the Commissioners' own doctrine. This doctrine "implies that neglect of vaccination increases not only the liability to attack from small-pox, but the liability to severe and to fatal attack . . ."

This argument may be accepted as valid, and applied to the small-pox statistics of the six above towns.

Fatality of Small-pox. In dealing with such fatality statistics it must be borne in mind that unless the number of facts on which the percentage is based is substantial, the percentage can carry little or no weight. The most serious errors made by physicians in concluding, for instance, that a given drug is particularly efficacious, have owed their origin either (*a*) to the fact that the number of cases treated was very small (on this point see also pp. 185 and 323), or (*b*) no allowance was made for age and other causes of variation in contrasting different therapeutical methods.

It is further to be remembered that small-pox, like all other infectious diseases, varies considerably in virulence, and therefore in fatality in different epidemics. Thus in the six towns already mentioned, it is probable that persons over 20 years of age are in about the same condition as regards vaccination; but the fatality among these was: Gloucester, 14·0; Sheffield (to date of census), 10·9; Warrington, 10·3; Dewsbury, 8·0; London, 7·0; and Leicester, 2·2 per cent.

The epidemic of small-pox in England and in other countries in 1870–72, probably owed its origin, in part at least, to the fact that the contagium of small-pox acquired at that time increased infectivity, owing to conditions—either biological or cosmical—of which we are at present ignorant.

It is asserted that the classification into vaccinated and unvaccinated groups cannot be relied upon as accurate. Every care has however been taken in obtaining accurate statistics for the six above towns, and it cannot reasonably be maintained that transference from one group to the other has occurred on a scale which would materially alter the broad result.

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* See pp. 10–15 of Mr. Paul's pamphlet.

In the six towns together, 2321 unvaccinated persons were attacked, of whom 35·4 per cent. died (Fig. 33).

Among the vaccinated persons at all ages who were attacked, 8744 or 5·2 per cent. died.

Among the unvaccinated, 1449 attacks were at ages under 10, with a fatality of 36·0 per cent.; 870 were over 10, with a fatality of 34·3 per cent. Among the vaccinated, 589 attacks were at ages under 10, with a fatality of 2·7 per cent.; 8131 attacks were at ages over 10, with a fatality of 5·4 per cent.

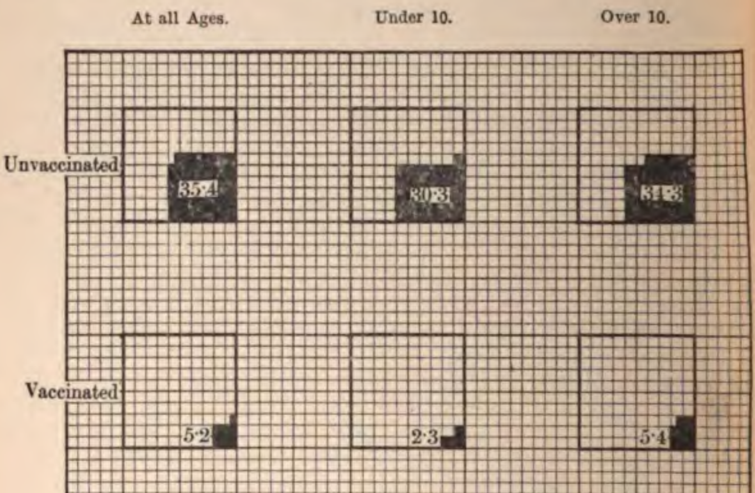


FIG. 33.

Percentage Fatality (Case Mortality) in Six Towns among Unvaccinated and Vaccinated under 10 and over 10 years of Age.

NOTE.—30·3 in the above diagram should be 36·0, and 2·3 should be 2·7, thus increasing the contrast between vaccinated and unvaccinated under 10 years of age.

In the following table the detailed facts for each of six towns, as given on pp. 55–58 of the Commissioners' report, are summarized :—

	Sheffield.*	London.	Dewsbury.	Warrington.	Leicester.	Gloucester.
Vaccinated cases under 10 .	353	110	44	33	2	26
Fatality per cent. . .	1·7	0·0	2·2	6·0	0·0	3·8
Unvaccinated cases under 10	288	228	174	32	107	680
Fatality per cent. . .	43·9	26·7	32·1	67·5	14·0	41·0
Vaccinated cases over 10 .	3774	1643	577	560	197	1185
Fatality per cent. . .	5·1	2·3	2·6	6·4	1·0	10·0
Unvaccinated cases over 10	322	181	192	36	51	88
Fatality per cent. . .	54·2	20·9	18·7	33·3	7·8	39·7

* Up to the date of Dr. Barry's census.

If the preceding figures are approximately true, even though a very liberal margin is allowed for alleged but unproved mistakes, it is clear that vaccination is followed by an immense improvement in the prospect of recovering from attack of small-pox.

Mr. Paul, in the pamphlet already mentioned, makes what he describes as a test contrast between Gloucester and Leicester. The argument of the Commissioners is, he states, "that no cause apart from vaccination can adequately account for the great variation in the small-pox fatality among the children of the six towns. What is the fact? That the widest variation of all is observed where something other than vaccination *must* account for it; because there was practically no vaccination in either case. These are the facts:—

	Unvaccinated.	Died.
Gloucester Children . .	96·31	39·66
Leicester Children . .	98·16	13·76"

The error in the above table consists in lumping vaccinated and unvaccinated children together. The table on p. 226 shows that among the two vaccinated children in Leicester who were attacked, no deaths occurred, while of the 107 unvaccinated children, 14 per cent. died. Similarly in Gloucester, the fatality among 26 vaccinated children was 3·8 per cent.; among 680 unvaccinated children, 41·0 per cent. No supposition about superior social status among the vaccinated will cover such differences as are here displayed. True, the fatality in both groups was much lower in Leicester than in Gloucester; *but the difference between the fatality in vaccinated and unvaccinated was greater in Leicester, both at ages under and over* 10, *than in Gloucester.*

Attack-rate among Vaccinated and Unvaccinated. Fig. 34, embodying the figures given on p. 65 of the report of the Royal Commission, shows the greater liability to attack by small-pox of the unvaccinated, and brings out the fact that the protection against attack imparted by vaccination decreases with advancing age. It is evident that the liability to attack depends primarily on contact with or proximity to sources of infection. Fig. 34 gives the percentage of attacks occurring *among persons living in infected houses*, classified according to vaccination and according to age under and over 10. The facts illustrated in Fig. 34 are based on all the houses from which the required information could be obtained. Their proportion to the total number of infected houses varied in different towns. Thus the information was available at Warrington for 437 out of 457 houses invaded, at Dewsbury for 544 out of 648 houses invaded, at Leicester for all invaded houses, at Gloucester for 899 out of a total of 1097 invaded houses.

Had space allowed, I had proposed to discuss the relationship between severity of attack of small-pox and vaccination, differentiating between the different qualities of vaccination: also to summarize the experience of the army and navy, and of other countries. For details on these and other points, the reader is referred to the Royal Commission's report. It has always appeared to me that the most convincing argument is that derived from the almost complete immunity from small-pox enjoyed by re-vaccinated nurses in small-pox hospitals. Thus, in the experience of the staff of the Metropolitan Asylums Board Hospitals, in the six years 1890–95, out of a staff varying from 1160 to 2514, the number who contracted scarlet fever, diphtheria, or typhoid fever during each year varied from 4·0 to 7·3 per cent. of the total staff; while out of a staff varying from 64 to 320, the percentage attacked by small-pox was *nil*, except in 1892, when it was 1·4, and in 1893 when it was 1·9.

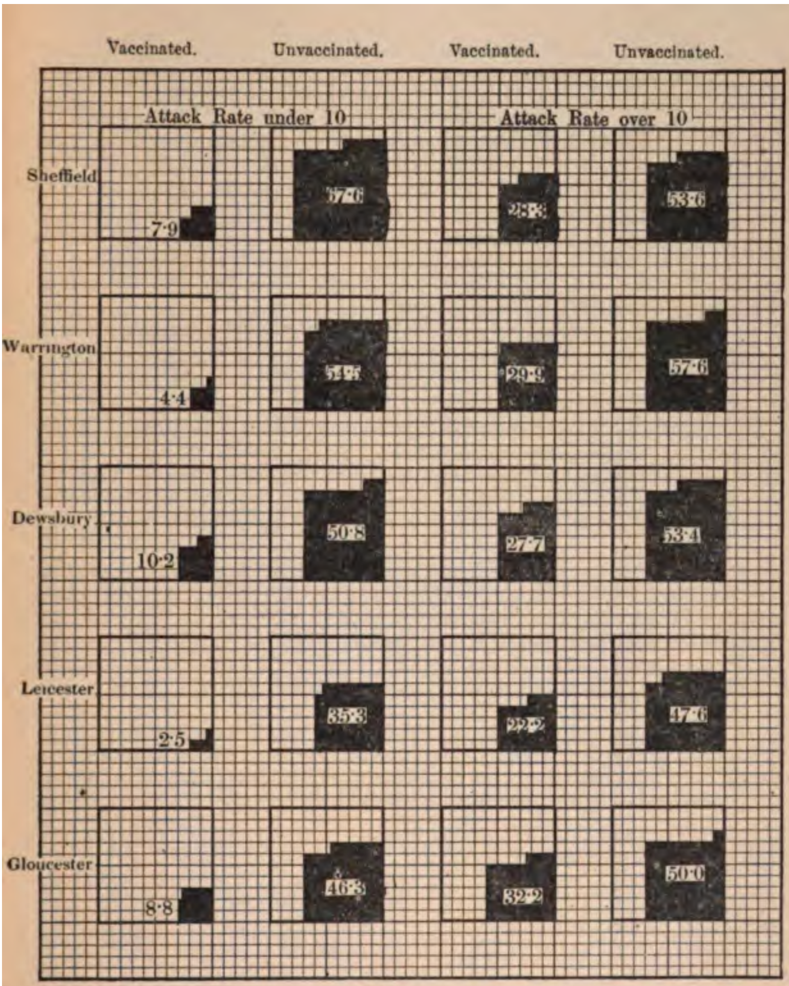


FIG. 34.

Rate of Attack per 100 Persons living in houses invaded by Small-pox among Vaccinated and Unvaccinated under 10 and over 10 years of Age.

The advantages of vaccination have been summarized as follows by the Royal Commission :—

"(1) That it diminishes the liability to be attacked by the disease.

"(2) That it modifies the character of the disease, and renders it (*a*) less fatal, and (*b*) of a milder or less severe type.

"(3) That the protection it affords against attacks of the disease is greatest during the years immediately succeeding the operation of vaccination. It is impossible to fix with precision the length of this period of highest protection. Though not in all cases the same, if a period is to be fixed, it might, we think, fairly be said to cover in general a period of nine or ten years.

"(4) That after the lapse of the period of highest protective potency, the efficacy of vaccination to protect against attack rapidly diminishes, but that it is still considerable in the next quinquennium, and possibly never altogether ceases.

"(5) That its power to modify the character of the disease is also greatest in the period in which its power to protect from attack is greatest, but that its power thus to modify the disease does not diminish as rapidly as its protective influence against attacks, and its efficacy during the later periods of life to modify the disease is still very considerable.

"(6) That re-vaccination restores the protection which lapse of time has diminished, but the evidence shows that this protection again diminishes, and that, to ensure the highest degree of protection which vaccination can give, the operation should be at intervals repeated.

"(7) That the beneficial effects of vaccination are most experienced by those in whose case it has been most thorough. We think it may fairly be concluded that where the vaccine matter is inserted in three or four places, it is more effectual than when introduced into one or two places only—and that if the vaccination marks are of an area of half a square inch, they indicate a better state of protection than if their area be at all considerably below this."

CHAPTER XX.

MORTALITY FROM CERTAIN INFECTIVE DISEASES.

PUERPERAL FEVER. The last edition of the nomenclature of the Royal College of Physicians states :—

> "The term 'Puerperal fever' should no longer be used. Pyæmia, Septicæmia, or Sapræmia, occurring in puerperal women should be described as 'Puerperal pyæmia,' 'Septicæmia,' or 'Sapræmia' respectively. The other conditions included under the term 'Puerperal fever' should be returned under Affections consequent on Parturition, the word 'Puerperal' being in all cases prefixed to the word denoting the local process."

It is doubtful, however, whether such exact definition is always possible. Most cases of puerperal fever are undoubtedly septic in origin; but it would often be difficult to go farther than this in stating their true pathological character. The advice given in the books of forms of certificates of death should, however, always be followed: "that whenever childbirth has occurred within one month before death, this fact should be registered in connection with the cause of death." This has been to a large extent neglected in the past by medical practitioners, and during the ten years 1881–90 letters sent out from the General Register office have resulted in over 1000 deaths being transferred to puerperal fever out of about 4000 deaths, the certified cause of which was "Peritonitis," occurring in women of child-bearing age. Again, of more than 3000 deaths returned as from pyæmia, blood-poisoning, etc., about 700 were ascertained to have been due to puerperal causes, and nearly half of 244 deaths ascribed in the certificates to metritis required to be similarly transferred.

Puerperal fever being confined to parturient women, it is preferable to calculate the death-rate from it in terms of the number of births rather than of the number of the entire population, as in the following table :—

ANNUAL NUMBER OF DEATHS OF MOTHERS TO 1000 CHILDREN BORN ALIVE.

Number of Deaths.	1851–60.	1861–70.	1871–80.	1881–90.	1891–96.
Puerperal Fever and other accidents of Childbirth	4·8	4·7	4·7	4·7	—
Puerperal Fever	1·5	1·5	2·1	2·6	2·5
Accidents of Childbirth	3·3	3·1	2·7	2·2	—

Thus in 1881–90 to every 1000 children born alive, 4·73 death of mothers occurred, or one maternal death to 211 live-born children.

It should be remembered that the number of *child-bearings* is not equivalent to the number of births. The births indicate the children born alive. Some other children are stillborn, and some are multiple at birth. Excluding the still-births, the number of child-bearings is obtained by reducing the number of births in about the proportion of 1 to 0·9902.

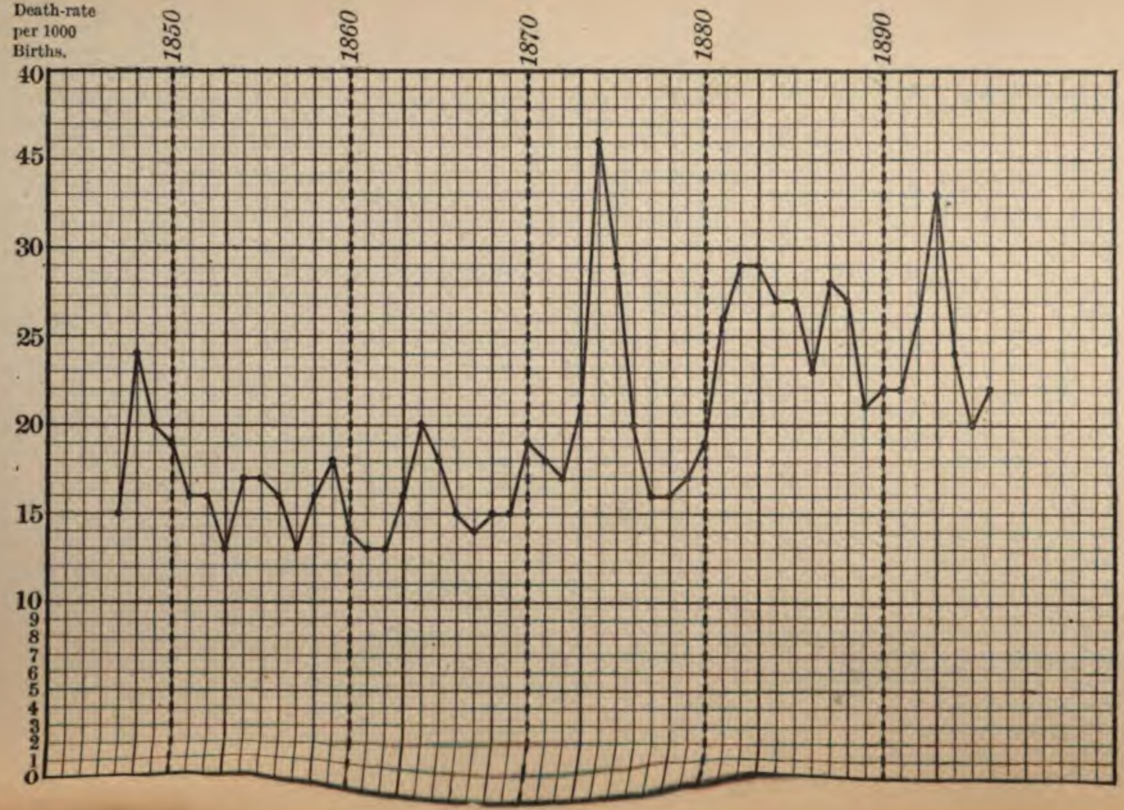
The following table (*Supplement to the Registrar-General's Fifty-fifth Annual Report*, part i. p. cx.) shows the incidence of puerperal mortality at different ages.

DEATH-RATE PER MILLION FEMALES LIVING AT EACH AGE-PERIOD FROM PUERPERAL FEVER AND CHILDBIRTH.

	All Ages.	10–	15–	20–	25–	35–	45–	55–
1861-70	321	0	161	633	921	888	60	—
1871-80	325	1	167	678	946	886	53	—
1881-90	297	0	129	601	888	802	43	0

The preceding table is not free from fallacies. The differences shown between the rates at each age-period may be caused solely by alterations in the risks of childbirth or by alterations in the birth-rate of the population at the same age-period. For accurate purposes what is required is a statement of the number of births classified according to the age of the mother, distinguishing between the births occurring within and without matrimony.

There is the further fallacy connected with average death-rates for series of years. This is brought out in the following curve,


Death-rate
per 1000
Births.
1850
1860
1870
1880
1890
40
45
30
25
20
15
10
9
8
7
6
5
4
3
2
1
0

which shows the mortality from puerperal fever in England and Wales from 1847 to 1896, stated in proportion to the number of births.

The curve shows years of greater mortality from this disease, which make one suspect the possibility of its partaking in some respects of the character of an epidemic disease. Longstaff has shown that the chief increase in the death-rate from this disease, as well as that of erysipelas, occurs in years of deficient rainfall. Both Gresswell and Longstaff have shown that the yearly mortality from scarlet fever is also inversely to the amount of rainfall. I have shown a similar relationship between deficient rainfall and the epidemic prevalence of diphtheria* and of rheumatic fever.† Now the years since 1881 have been almost without exception years of deficient rainfall, and this protracted deficiency of rainfall has corresponded with a protracted excess of puerperal fever, as well as of the diseases mentioned above. Another factor came into operation in 1881, and has been continued in subsequent years, viz., the sending out letters of inquiry from the General Register Office, as already indicated. It may, therefore, be that these two factors have produced an increase of registered mortality from puerperal fever, and that there has been no greater carelessness in precautions against sepsis on the part of accoucheurs or midwives, as the figures might at first sight indicate. If this supposition is correct, then with the next cycle of wet seasons puerperal mortality will again decline. It may decline beyond what may be described as the "normal" extent, if antiseptic precautions are rigidly practised in connection with midwifery.

A further subject of inquiry is the relationship of puerperal mortality to the primiparous or multiparous condition. No official English data are available on this point. Valuable information, both for the business of life insurance and for medical purposes, would be secured by making it obligatory to insert the ages of the parents of the children whose births are registered, and the position of the child in the family. (See p. 69.)

Mr. T. A. Coghlan, government statistician for New South Wales, gives some valuable information on these points, based on the 115,669 confinements and 813 deaths due to childbirth registered in New South Wales in the four years 1893–6.

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* *Epidemic Diphtheria: a Research on the Origin and Spread of the Disease*, 1898.

† See Milroy Lectures by the Author. *Lancet*, March 9th and 16th, 1895.

The births and deaths in childbirth being arranged according to the number of the confinements, show a probability of death in the first confinement of 0·0087, in the second 0·0066, in the fifth of 0·0052, in the tenth of 0·0097, in the thirteenth of 0·0168. The risk attending the first birth is greater than that at any subsequent one up to the ninth. The minimum risk appears to be at the fourth confinement, but the increase in the risk at subsequent confinements may be due to the increased age of the mother. When the first confinements are arranged according to the age of the mother, it is seen that the risk attendant upon a first birth is at a minimum at the twenty-second and twenty-third years, and after five years increases rather rapidly with age. The following table summarizes some of Mr. Coghlan's most important results (*Journ. Royal Statist. Soc.*, vol. lxi. part iii.) :—

Table showing for New South Wales, 1893–96, the unadjusted Death-rates per cent. of Childbed for Quinquennial Groups of Ages.

Age.	Coghlan, New South Wales. Deaths of Childbed.		
	Primiparæ.	Primiparæ and Multiparæ combined.	
	Married.	Married.	Unmarried.
17–19	0·860	0·726	1·199
20–24	0·634	0·439	1·095
25–29	0·935	0·508	0·748
30–34	1·507	0·674	1·038
35–39	1·389	0·855	0·189
40–44	3·247	1·132	0·602

From his adjusted figures Mr. Coghlan comes to the conclusion that "the risk of unmarried women in childbirth is at every age greater than for the married, the disproportion in the ratios being greatest at the lower ages."

N.B.—Mr. Coghlan employs a graphic method of adjustment similar to that described on pp. 246 and 265.

The *local incidence* of puerperal mortality for each county is given in the *Supplement to the Fifty-fifth Annual Report of the Registrar-General*, p. lii. The average number of deaths from puerperal fever and other accidents of childbirth per 1000 births in 1881–90 was 4·7 for England and Wales, varying from 6·7 in

North Wales, 6·1 South Wales, and 5·5 Shropshire, Lancashire, and Cheshire, to 4·0 in Kent and Bedfordshire, 3·9 London, 3·7 Suffolk, 3·5 Rutlandshire, and 3·3 in Huntingdonshire. A fallacy lurks in average death-rates for a disease, such as puerperal fever, which is much more prevalent in certain years than in others. (See p. 232.)

Tubercular Diseases. The two following tables give the chief figures as to the mortality from these diseases in England. In the first table the corresponding data for diseases of the respiratory organs (other than phthisis) are given for comparison:—

ENGLAND AND WALES: MORTALITY FROM PHTHISIS, OTHER TUBERCULAR DISEASES, AND DISEASES OF RESPIRATORY ORGANS PER MILLION PERSONS LIVING AT ALL AGES.

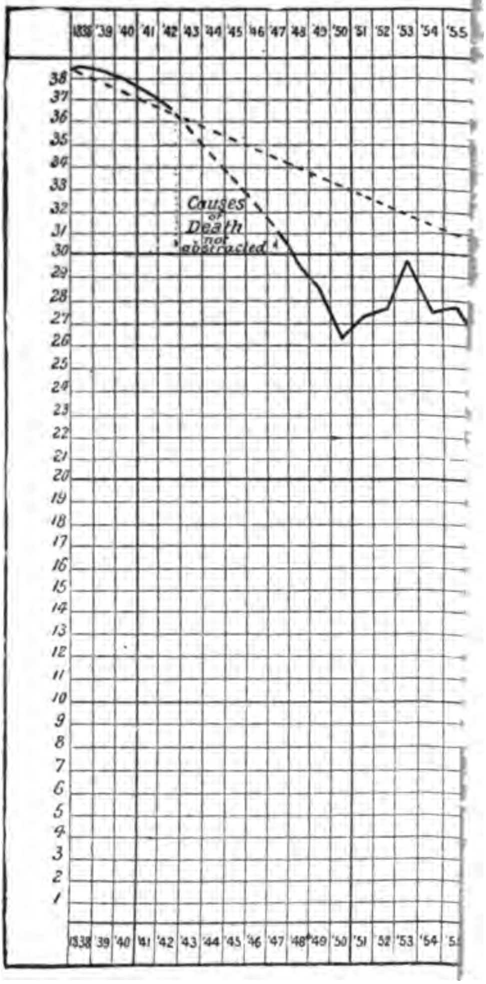
	1861–70.	1871–80.	1881–90.	1891–95.	1896.
Phthisis	2475	2116	1724	1464	1307
Other Tubercular Diseases .	765	747	696	660	685
Diseases of Respiratory System	3591	3899	3729	3747	3034

In the following table the facts as to phthisis are classified according to age and sex:—

MORTALITY FROM PHTHISIS IN GROUPS OF YEARS, 1861–96, PER MILLION OF EACH SEX LIVING AT EACH GROUP OF AGES.

Periods.	All Ages.	0–	5–	10–	15–	20–	25–	35–	45–	55–	65–	75 and upwards.
MALES.												
1851–60 . .	2579	1329	525	763	2399	4052	4031	4004	3830	3331	2389	928
1861–70 . .	2467	990	431	665	2190	3883	4094	4166	3861	3297	2024	659
1871–80 . .	2209	783	340	481	1675	3092	3699	4120	3860	3195	1924	603
1881–90 . .	1847	553	253	342	1287	2333	3024	3562	3488	2916	1816	688
1891–95 . .	1633	467	197	260	1076	2026	2548	3268	3205	2687	1572	563
1896 . .	1485	392	150	203	913	1848	2285	3029	3043	2599	1329	512
FEMALES.												
1851–60 . .	2774	1281	620	1293	3516	4288	4575	4178	3121	2383	1635	716
1861–70 . .	2483	947	477	1045	3112	3967	4378	3900	2850	2065	1239	447
1871–80 . .	2028	750	375	846	2397	3140	3543	3401	2464	1777	1093	407
1881–90 . .	1609	518	327	699	1800	2315	2787	2730	2053	1512	974	397
1891–95 . .	1303	421	260	561	1428	1740	2155	2305	1742	1294	800	350
1896 . .	1139	349	204	454	1183	1562	1874	2090	1543	1170	676	375

DEATH-RATES from PHTHISIS



Face page 237.

t thus appears that the death-rate per 1000 at all ages has lined from 2·58 for males and 2·77 for females to 1·48 for les and 1·14 for females. The accompanying diagram (Fig. 36) Dr. Ransome (*Lancet*, July 11th, 1896) graphically represents e decline for a still longer period. Between 1838 and 1894 the hthisis death-rate had declined from over 3·8 to only 1·38 per 000 inhabitants. The line joining the highest and the lowest oints of the curve (dotted lines) is approximately straight, and ot a hyperbola, thus demonstrating, as pointed out by Dr. Venn, hat the rate of diminution is an increasing one. The fall would ave been more gradual had the percentage of diminution reained constant during the period under observation.

From the year 1851 to 1865 the phthisis death-rate was greater mong females than among males, the difference between the two radually diminishing. Since 1866 the phthisis-rate has been niformly in excess among males, and increasingly so.

The following table shows that while the decrease of mortality rom phthisis among males has amounted to 37 per cent., that mong females has been 53 per cent.

In the same table I have calculated the percentage reduction at ach age-group for the two sexes, the comparison being between he decennium 1851–60 and the quinquennium 1891–95.

PERCENTAGE REDUCTION OF PHTHISIS DEATH-RATE BETWEEN 1851–60 AND 1891–95.

	All Ages.	0–	5–	10–	15–	20–	25–	35–	45–	55–	65–	75 and upwards.
Males	37	65	63	66	55	50	37	18	16	19	34	39
Females	53	67	58	57	59	59	53	45	44	46	51	51

The decline in phthisis mortality, it will be seen, is greater at nearly all ages in females than in males, the only exceptions being between 5 and 15 years of age.

Another interesting point can be gathered from the table on p. 236, and is more clearly brought out in the following table (*Report of Royal Commission on Tuberculosis*, Part ii., Appendix C, Dr. Tatham):—

AGES OF MAXIMUM MORTALITY FROM PHTHISIS.

(The age-groups in heavy type have the maximum rates, the others being approximate.)

Periods.	Males.	Females.
1851-60 . .	**20-25**, 25-35, 35-45	**25-35**
1861-70 . .	25-35, **35-45**	**25-35**
1871-80 . .	**35-45**	**25-35**
1881-85 . .	**35-45**	**25-35**
1886-90 . .	35-45, **45-55**	**25-35**, 35-45
1891-95 . .	**35-45**, 45-55	**35-45**

The age of maximum phthisis mortality has been postponed in both sexes. This may be ascribed to a greater saving of life at those ages formerly most liable to death from phthisis, or to a postponement of death in those who are attacked by the disease. Probably both causes are at work.

The question arises as to how far the reduction in registered mortality from phthisis is real, and how far it is due to more accurate diagnosis and certification of deaths.

It is possible that, owing to more accurate statemen of causes of death, there has been considerable transference from phthisis to diseases (other than phthisis) of the respiratory organs. (See table, p. 236.) The term phthisis is now not so loosely used as formerly, when any chronic chest affection received this name. But that this is by no means a complete explanation of the decrease in phthisis, is evidenced by the fact that while the mortality from phthisis has decreased at all age-groups, the mortality from respiratory diseases has only increased under 5 and over 75 years of age. Furthermore, the mortality from phthisis chiefly takes place between the ages of 15-55 years, while that from respiratory diseases is very low during these years, and greatest at the extremes of life.

In the following table I have calculated the reduction at each age-group between 1861-70 and 1896 for phthisis and for diseases of the respiratory system (exclusive of croup). In this instance 1896 is taken rather than the quinquennium 1891-95, in order that the disturbing influence of influenza may be less operative.

PERCENTAGE REDUCTION OF DEATH-RATE AT EACH AGE-GROUP BETWEEN 1861-70 AND 1896.

	All Ages.	0-	5-	10-	15-	20-	25-	35-	45-	55-	65-	75 and upwards
		PHTHISIS.										
Males	40	60	65	66	58	52	44	27	21	21	44	22
Females	52	63	57	37	62	61	57	46	46	43	45	16
		RESPIRATORY DISEASES.										
Males	10	+5	5	24	9	10	7	6	11	13	20	7
Females	11	+4	11	32	36	36	28	21	21	21	20	+4

NOTE.—All the figures represent decreases, except those preceded by +.

In recent years there has been an increasing tendency to register deaths as due to "tuberculosis" or "general tuberculosis," which would formerly have been returned as phthisis. The result has been some exaggeration of the decline of the phthisis death-rate. The same cause has tended to keep up the death-rate from other tubercular diseases. Other causes have contributed to this effect. Many deaths now returned as tubercular meningitis would have appeared formerly as "fever" or "brain fever." It is probable that more cases of simple meningitis are returned as tubercular than the reverse. Again, many deaths formerly returned as marasmus, etc., are now ascribed to tabes mesenterica, and many more articular and other strumous diseases have their tubercular character plainly stated than in former years. There is strong reason for thinking that many deaths are now returned as tabes mesenterica where an autopsy would prove the absence of tubercular disease.

The death-rate from tubercular meningitis (acute hydrocephalus) was 380 per million in 1880, falling to 233 in 1896. Tabes mesenterica (a time-honoured term, probably including certain other non-tubercular diseases besides tubercular affections of the abdomen and its glands) declined from 403 in 1880 to 214 in 1896; other forms of tuberculosis increased from 142 in 1880 to 200 in 1896. In view of the preceding considerations, it is probable that the decline in all other tubercular affections than phthisis is greater than the official figures show.

The amount of mortality due to tubercular diseases still remains appallingly great. Thus, during 1896, 7·6 per cent. of the total English mortality was caused by phthisis, and 11·6 per cent. by all tubercular diseases together. Taking 15 to 55 as the most important working years of life, it is important to note that in the same year 26·6 per cent. of the total deaths among males at these ages were caused by phthisis, and 28·9 per cent. by all tubercular diseases together.

The *local distribution* of phthisis mortality is given in the *Supplement to the Fifty-fifth Annual Report of the Registrar-General*, part i. p. lvii. *et seq.*, the death-rates being calculated per standard million of population. Thus stated the phthisis death-rate in 1881–90 was 1724 for England and Wales, the highest being 2112 North Wales, 2095 Northumberland, 2003 South Wales, and 2001 London; the lowest 1217 Worcestershire, 1304 Herefordshire, and 1315 Leicestershire. In London, Hampshire, Sussex, Warwickshire, Surrey, Middlesex, and Worcestershire the phthisis death-rate of males exceeded that of females by proportions varying from 27 to 55 per cent. In South Wales, Durham, Huntingdonshire, Lincolnshire, North Riding of Yorkshire, Monmouthshire, and Rutlandshire, on the other hand, the male rate was from 12 to 21 per cent. below the female rate. The phthisis death-rate of London for 1881–90 is vitiated as regards both inclusion and exclusion by the lack of adjustment for deaths occurring in institutions within and without the metropolis. Such adjustments will be obtainable for more recent years.

CHAPTER XXI.

MORTALITY FROM CANCER AND CERTAIN OTHER CAUSES.

CANCER. The registered mortality from cancer (including under this name the various forms of malignant disease) has steadily increased, as shown in the following table:—

MORTALITY FROM CANCER IN ENGLAND AND WALES PER MILLION LIVING.

	1851–60.	1861–70.	1871–80.	1881–90.	1891–95.	1896.
Males . .	195	242	312	430	—	618
Females . .	434	519	617	739	—	901
Persons . .	317	384	468	589	712	764

Cancer is a disease of later adult life, as is shown by the following table, in which the death-rates per million living at each age-period in 1861–70 and in 1896 are compared:—

DEATH-RATES FROM CANCER PER MILLION LIVING IN EACH AGE-PERIOD, 1861–70 AND 1896.

	Periods.	All Ages.	0–	5–	10–	15–	20–	25–	35–	45–	55–	65–	75 & upwards.
	MALES.												
Death-rates .	1861–70	242	13	8	7	18	26	60	204	536	1201	1862	2258
	1896	618	27	23	19	42	48	89	419	1362	3340	5427	5992
Percentage Increase between 1861–70 and 1896.		155	109	192	175	137	86	49	106	154	179	177	165
	FEMALES.												
Death-rates .	1861–70	519	13	7	7	16	32	161	669	1530	2291	2791	2786
	1896	901	32	11	11	30	42	175	933	2308	4187	5686	6539
Percentage Increase between 1861–70 and 1896.		74	150	60	60	91	33	9	40	51	83	104	135

The mortality registered from cancer was two and a half times as great among males and one and three-quarter times as great among females in 1896 as that registered in 1861–70. Part at least of this increase is, however, only apparent, due to the improved diagnosis and more careful statement of causes of death. This is shown (1) by the steady decrease in the number of deaths from tumour, abdominal disease, and other ill-defined forms of disease; and (2) by the fact that the increase of mortality from cancer is much greater among males than among females. (See table, p. 241.)

This greater increase in the male mortality from cancer is most easily understood on the hypothesis that the rise is in great measure apparent and due to better diagnosis; the cancerous affections of males being internal in a much larger proportion than those of females. Had the increase been altogether real, it is difficult to understand why it should affect males so much more than females.

(3) The system of inquiry on the part of the General Register Office, when certificates of a dubious character are received, was the means of increasing the cancer death-rate in 1881–90 by 6 per million.

(4) Where more accurate statistics are available the increase in the cancer death-rate is seen to be on a smaller scale. Mr. George King, F.I.A., and the author have shown (*Proc. Roy. Soc.*, vol. liv.) that when the national statistics of England, Scotland, and Ireland are compared with those of lives insured in the Scottish Widows' Fund Life Assurance Society, the results depicted in Fig. 37 are obtained.

Corrections for age-distribution have been made, to be hereafter explained. The importance of these corrections may be gathered from the following:—

COMPARISON OF CORRECTED AND UNCORRECTED CANCER DEATH-RATES.

Period.	Not Corrected.		Corrected.	
	England.	Ireland.	England.	Ireland.
1860–66	498	553	625	614
1867–73	597	627	747	661
1874–80	719	680	911	699
1881–87	902	807	1152	824
1888–90	1091	894	1393	912

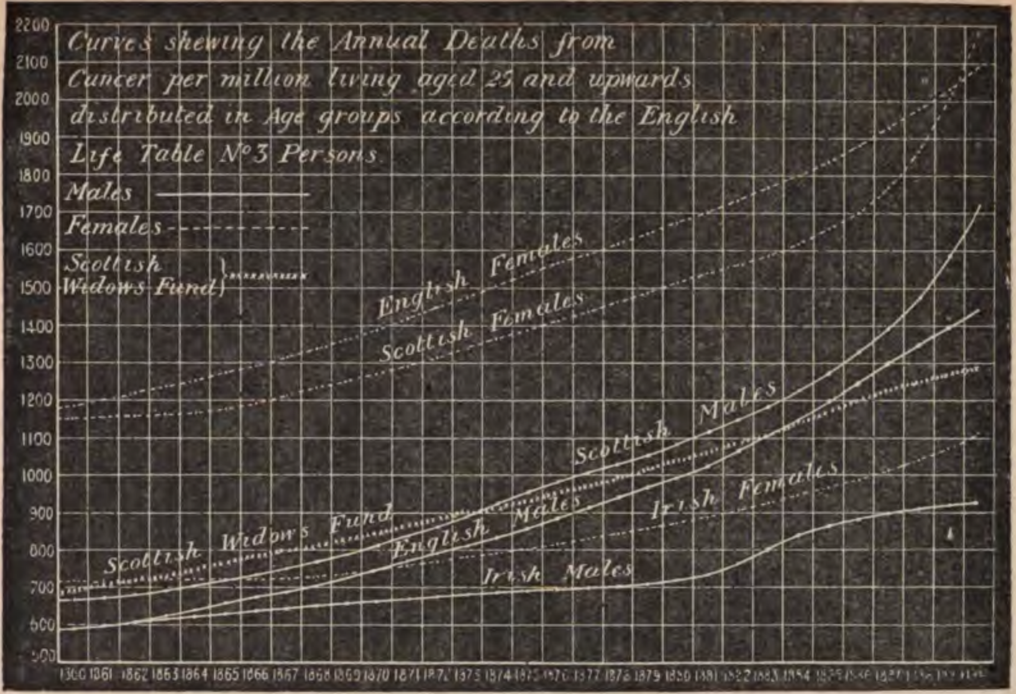

Curves shewing the Annual Deaths from
Cancer per million living aged 25 and upwards
distributed in Age groups according to the English
Life Table No 3 Persons
Males
Females
Scottish Widows Fund
English Females
Scottish Females
Scottish Males
Scottish Widows Fund
English Males
Irish Females
Irish Males
2200
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
1860 1861 1862 1863 1864 1865 1866 1867 1868 1869 1870 1871 1872 1873 1874 1875 1876 1877 1878 1879 1880 1881 1882 1883 1884 1885 1886 1887 1888 1889

Fig 37.

It will be observed that by the uncorrected figures Ireland stands a little above England for the first two periods, and a little below it for the other three, but that no very great difference appears between the rates for the two countries. The corrected figures, however, show that Ireland stands below England throughout, so that in the first two periods the position of the countries is reversed by the correction, and in the last three periods the difference in favour of Ireland is very great indeed. It is evident that the ordinary method of presenting the statistics exaggerates the rate of cancer in Ireland as compared with England, a result which might have been expected, owing to the age-distribution of the populations of the two countries.

The comparative immunity from cancer shown by the Irish curves is probably caused, in part at least, by deficiencies of diagnosis and certification, associated with the sparsity of population and poverty of that country. For our present purpose the main interest of Fig. 37 lies in the Scottish Widows' curve. This has the easiest gradient of all, strongly confirming the view that the apparent increase of cancer mortality is caused by increased accuracy in diagnosis and certification. The policy holders in the Scottish Widows' Office are presumably well-to-do and able to secure on the whole better medical attendance than the mass of the people, and their death-returns consequently show to a less extent the effect of increased accuracy of diagnosis and certification.

Another reason for thinking that the apparent increase in cancer is at any rate mostly due to improved diagnosis is derived from a comparison of the curves for males and females respectively. It will be noticed that the curves for females are always the higher, and that in each pair of curves the difference is practically constant throughout the entire period. Now, if there were a real increase of cancer, there is no sufficient ground for thinking that this would be confined to any one set of organs of the body, or would affect one sex more than another; and in such case the difference between the cancer in males and females would be a percentage of the total, and would increase at the same rate as the curves themselves rise, and consequently the curves for males and females would tend to widen their distance apart. This, however, is not so. In each of the three pairs the curves for males and females do not diverge, but, if anything, tend to approximate.

It may be urged that, notwithstanding what has been said above, cancer may have increased more in certain parts of the body than in others, and that, although it has really increased in both sexes, it has increased in such greater proportion among males, that the curves for the two sexes remain parallel. This view, however, is contradicted by the Frankfort statistics given in the same paper. It is not necessary to reproduce these figures here. Briefly they show that when cancer deaths in that city are classified, as their very complete character enables them to be, into accessible, inaccessible, and cancer of undefined position, between 1860 and 1889 there has been no increase in the mortality from the cancer affecting positions in which it is easily accessible and detected.

From the above and other considerations which cannot be detailed here, Mr. King and the author arrived at the conclusion that the evidence of increase in cancer-mortality is altogether insufficient, and that such increase has probably not occurred. The increase is, in other words, only apparent, being due to improvement in diagnosis and more careful certification of the causes of death.

A recent writer has advanced the theory that the higher mortality from cancer is caused by the greater number of survivors to what may be called the cancer-ages. This explanation implies a mental confusion between *deaths* and *death-rates*. When the death-rates at each group of ages, as on p. 241, are given, this point does not arise; and when the death-rate is stated more generally, correction can be made by applying the death-rate at different age-groups to a standard population (as on p. 173), thus eliminating entirely the question of a larger number of survivors to higher ages. The statement that the decrease in the mortality from phthisis involves an increased mortality from cancer, implies the same mental confusion between mortality and rate of mortality. A method of applying this correction was described by Mr. King and the author in 1893 (*op. cit.*). The standard population taken by them was that of the English Life-Table, No. 3, Persons, viz. :—

Ages.	Population.
25–35	260,259
35–45	232,106
45–55	199,912
55–65	158,812
65–75	102,196
75 and upwards	46,715
	1,000,000

The death-rates in the populations to be contrasted having been obtained for the age-groups 25–35, 35–45, etc., they were each multiplied into the populations of the above table. The sum of the products for any particular period of years gave the number of deaths from cancer per annum among one million persons aged 25 and upwards. Then, by comparing the same for, say, the period 1860–66 with that for the period 1881–87, we ascertain in which direction the apparent death-rate from cancer is progressing. By adopting this course in each instance, the observations for all the different localities and all the different periods of years are reduced to one common standard, and the errors are eliminated which would arise from variations in the age-distribution of the population.

It may be interesting at this point briefly to describe the method by which the mean cancer death-rates for series of years were changed into figures for single years. This might have been accomplished by the application of analytical processes. The method adopted was an application of the graphical method of constructing life-tables. (See p. 265.)

As showing the application of the method to the present inquiry, Fig. 38, relating to England and Wales, is given, of which a very few words of explanation will suffice. Along the abscissa axis are marked off equal lengths to represent each of the periods of seven years under review, with a portion of proportionate length for the three years 1888–90; and along the ordinate axis the rates of mortality per million are marked off. Rectangles are then erected, the areas of which are to represent the number of deaths from cancer in each of the septennial periods. Thus the area of the rectangle for the septennium 1860–66 is 4375 for males, as its base is seven and its altitude 625. Similarly for the other rectangles.

Through the tops of the rectangles a continuous curve is then drawn in such a way that the area cut off is exactly equal to the area added. The length of the ordinate of the curve, which is central to any particular year, will then give the deaths from cancer in that year; and the accuracy of the drawing of the curve will be proved, if there be no sudden change of direction, and if the sum of the numbers for the seven years of a septennium is equal to the area of the rectangle for that septennium. Fig. 38 shows the curves for England and Wales, that for males being an unbroken line, and that for females a dotted line. Similar curves were prepared for all the observations, and these are collected in Fig. 37, so that they may be easily compared.

In the *Supplement to the Fifty-fifth Annual Report of the Registrar-General* (p. liii. *et seq.*) are given the results of the calculation of the distribution of cancer mortality in the different English counties in terms of a standard million of population over 35 years of age. The result is some striking alterations of cancer death-rates. Thus, after such a correction has been

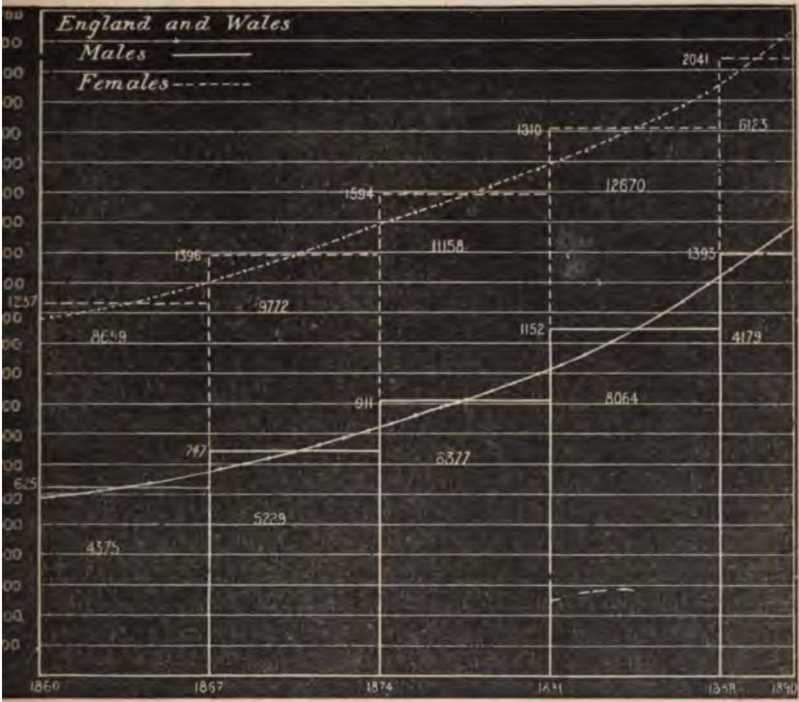


Fig. 38.

Showing how the Cancer Death-rate for each year is obtained from the Mean Cancer Death-rate for Septennial-periods.

made, the cancer mortality of Huntingdonshire is to that of Durham as 127 only to 100, while the crude-rate at all ages is as 208 to 100. Similarly the difference between the crude-rates of Cornwall and London is only about 2 per cent., that of their corrected rates 38 per cent.

The **local distribution** of cancer in England and Wales in 1881–90, calculated by the corrected method indicated above, is given on p. lv. of the last decennial supplement. The average annual death-rate of a standard million, above 35 years of age, in England and Wales was 1844. The highest cancer death-rates were London, 2250; Huntingdonshire, 2157; Cambridgeshire, 2012; Sussex, 1999; Warwickshire, 1976; the lowest, Monmouthshire, 1574; Dorsetshire and Buckinghamshire, 1578; Derbyshire, 1597; Wiltshire, 1604; and Cornwall, 1630. The high corrected cancer death-rate of London, like that from phthisis, is largely due to the presence of hospitals for the special treatment of these diseases. The above correction, it will be noted, is for variations of age-distribution, not for the presence of hospitals attracting patients from other districts.

Heredity in Cancer. The fact that several members in successive generations of a given family have died from cancer is commonly accepted as proof that the disease is hereditary. This is far from being the case. Cancer causes a certain average number of deaths among a given number of persons. The death-rate from cancer, as will be seen from the table on p. 241, is insignificant until the age of 35 is reached, rapidly increasing at each higher age-period. On the basis of the national figures for 1887–89, one out of twenty-one men and one out of twelve women, who reach the age of 35, die eventually of cancerous disease. (*Fifty-second Annual Report of the Registrar-General*, 1889, p. xiv.) For the following remarks on this important point, I am indebted to Mr. G. King, F.I.A. Given a certain probability of death from cancer, and knowing the number of a family, it is easy to calculate the probability of one, two, or more of them dying of cancer quite independently of heredity. Even if heredity were proved to be absolutely inoperative, it is certain that there would be families among whom numerous deaths from cancer would occur. It does not prove heredity to show that in one family, five deaths, say, occurred from cancer. This might happen from mere chance, and in fact such cases must occur without heredity at all. De Morgan worked out the probability of 1000 successive heads being thrown in tossing a coin, and he showed that given a sufficient number of people starting to toss coins, it was a certainty that at least one of them would toss 1000 consecutive heads. So, given a sufficient number of families, it is a certainty, even if there be no such thing as heredity, that of at least one family, say ten members will die of cancer. The only absolute proof of heredity would be to show that cancer occurred frequently in certain families, and practically nowhere else; short of this the probability of heredity of cancer would be increased if it could be shown that cancer was much more common in certain families than in the average for the whole community, due allowance being made for variations in age and sex-distribution.

Diabetes. The registered death-rate from diabetes mellitus has steadily increased during the last twenty years. In 1895 it was 75, and in 1896 it was 74 per million, as compared with 41 in 1877. The death-rate for males in 1896 was 83, and for females, 66 per million.

Much of this apparent increase is doubtless due to greater care in diagnosis and in certification; but it is also suggested that there has been a real increase due to the increased mental strain and worry of modern life, a similar explanation being given for the registered increase of chronic renal disease.

The question as to whether there has been any real increase must still be left undecided. The disease is chiefly fatal after the twenty-fifth year of life. In 1881–90, the death-rates among males at the age-periods 45–55, 55–65, 65–75, and 75 and upwards were equal to 134, 282, 397, and 314 per million living, as compared with 96, 181, 247, and 172 in 1871–80.

The mean annual mortality from diabetes in England and Wales is stated in the *Registrar-General's Forty-eighth Annual Report*, 1885, to be 26 per cent. above that of Scotland, and 40 per cent. above that of Ireland. This is in accord with the distribution of diabetic mortality as shown in the same report, which appears to show a remarkable inverse relation between the amount of diabetes and the amount of rainfall.

Dietetic Diseases. These are deaths from deficiency of diet (scurvy, starvation, want of breast-milk) and intemperance, embracing chronic alcoholism and delirium tremens. In 1896, these diseases gave a registered death-rate of 80 per million living, 68 of which was attributed to intemperance. The deaths returned under this head are, however, not trustworthy; alcoholism causes in reality an enormously greater mortality than is ascribed to it.

In 1861–65, the mean death-rate registered as caused by intemperance was 42 per million. It steadily increased, in 1891–95 reaching 68 per million. This increase is almost certainly due to more correct certification of deaths.

One of the commonest diseases due to alcoholism is *cirrhosis of the liver;* and as this is the chief cause of mortality under the heading "liver diseases and ascites," the latter may be taken as a fairly correct index of the amount of alcoholic excess in England and Wales.

Annual Death-rate per Million Persons Living from Diseases of the Liver and Ascites.

Period.	3 years. 1858–60.	5 years. 1861–65.	5 years. 1866–70.	5 years. 1871–75.	5 years. 1876–80.	5 years. 1881–85.	5 years. 1886–90.	5 years. 1891–95.
Death-rate per million	394	416	418	428	424	372	325	270

It will be seen that the mortality from liver diseases has been declining for some years, and this coincides with what is known of the improved alcoholic habits of the community. Here, again, difficulty arises when an attempt is made to subdivide liver diseases. Thus the death-rate per million ascribed to cirrhosis among males has increased from forty-three in 1861–70 to 140 in 1881–90; that ascribed to ascites has decreased from twenty-six to nine, and that from other liver diseases has decreased from 366 to 210. It is probable, on the whole, that there has been a decline in alcoholism and its consequences, notwithstanding the registered increase in cirrhosis of the liver.

Developmental Diseases. The following table shows that the death-rate from premature birth and from congenital defects has steadily increased, being higher in 1896 than in any previous year. The best way to estimate the number of deaths resulting from premature birth and from congenital defects is *in proportion to the total number of births,* as in the following table. By this means, the disturbing influence of the low birth-rate in recent years is removed.

Period.	Deaths to 1000 Births.		Death-rate per million Persons.
	Premature Birth.	Congenital Defects.	Old Age.
1861–65 . .	11·19	1·76	1353
1866–70 . .	11·50	1·84	1276
1871–75 . .	12·60	1·85	1207
1876–80 . .	13·38	2 39	1072
1881–85 . .	14·18	3·23	1014
1886–90 . .	16·15	3·39	976
1891–95 . .	18·42	3·87	929
1896 . . .	18·99	4·16	850

The total infantile mortality in 1896 was 148, and in the ten years 1886–95 it also averaged 148 per 1000 births. It may be surmised that as the infantile mortality from all causes together has not increased, part of the increased mortality from premature birth is only apparent, and due to transference from other headings. Some influence may also be ascribed to the markedly increased employment of women in industrial occupations.

The above table shows a falling off in the death-rate from *old age.* If this were a real falling off, it would not be an indisputable advantage, as most people would prefer to die of old age. The decline under this head is, however, chiefly due to an improved specification of the causes of which the old die. The mortality from "old age" is always higher in cold seasons, cold being the special enemy of the old, as heat is of the young.

Diseases of the Nervous System show a death-rate per million of 1546 in 1861–65, and of 1600 in 1891–95, the highest being 1808 in 1881–85. **Convulsions** as a cause of death are properly not included in the above, the death-rate ascribed to this cause having declined from 1258 in 1861–65 to 688 in 1891–95. **Diseases of the Circulatory System** have increased in registered mortality from 997 per million in 1861–65 to 1677 in 1891–95.

Much of this increase is probably due to transference from such headings as debility, old age, and the like, an assumption which is supported by the fact that the main increase is in the later age-periods. Thus at the age-period 75 and upwards the death-rate per million from these diseases has increased from 9186 in 1861–70 to 18,864 in 1881–90, while at the age-period 25–35 the increase is only from 1019 to 1345. Some of the increase is also possibly due to the institution of letters of inquiry from the General Register Office when "dropsy" was returned as the cause of death. Whether there is any real increase not explained by the preceding or similar considerations is still dubious.

Urinary Diseases caused a death-rate per million living of 453 in 1891–95, as compared with 246 in 1861–65. We have also to bear in mind the diminution under the heading "dropsy" in connection with the registered increase under this heading. The uncertain amount of allowance for transference of diseases (due to better diagnosis or more careful certification) is a stumbling-block at every step. The weighty remarks of the Registrar-General on this point may be quoted: "To be without trustworthy means of comparison is doubtless an evil, but to ignore the differences and to deal with the records as thoroughly reliable would be still worse, for it is far better to be without statistics at all, than to be misled by false ones."

Violence. The following table shows the death-rate from the various forms of violence in successive year-periods.

MEAN ANNUAL DEATH-RATE PER MILLION LIVING FROM VIOLENCE

	1861–65.	1866–70.	1871–75.	1876–80.	1881–85.	1886–90.	1891–95.
Accident and Negligence	690	678	671	630	580	544	564
Homicide .	19	19	17	14	13	11	10
Suicide . .	65	66	66	74	75	79	89
Execution .	0·8	0·4	0·4	1·0	0·4	0·8	0·4

The death-rate from violence is much greater in the male sex. Thus in 1881–90 it averaged 968 among males, and 347 among females. The excess among males is not solely due to occupational dangers, as it is seen in the first five years of life, in which the death-rates per million in the two sexes are 1266 and 1019 respectively. The death-rate from accident has gradually declined, but suicide is on the increase.

The relative incidence of the various forms of accident or negligence in the two sexes can be gathered from the following figures for 1896:—

DEATH-RATE PER MILLION LIVING OF EACH SEX FROM ACCIDENT OR NEGLIGENCE, 1896.

	Males.	Females.
In Mines and Quarries	70	0
Vehicles and Horses	144	18
Ships, Boats, and Docks (not Drowning) . .	17	0
Building Operations	15	—
Machinery	13	1
Weapons and Implements	8	1
Burns and Scalds	74	93
Poisons, Poisonous Vapours	27	14
Drowning	135	25
Suffocation	78	66
Falls	101	74
Weather Agencies	13	4
Otherwise, or not stated	86	32
Total	781	328

The proportion of the different forms of suicide in the two sexes can be gathered from the following table, which deals with actual deaths not death-rates in England during 1896:—

	Deaths from Suicide, 1896.	
	Males.	Females.
Vehicles and Horses		
(*a*) Railways	94	14
(*b*) Vehicles other than railways . .	3	—
Weapons and Implements	551	78
Burns, Scalds, and Explosives	2	3
Poisons and Poisonous Vapours	279	193
Drowning	347	207
Suffocation	602	139
Falls	49	20
Otherwise, or not stated	52	23
Total . . .	1979	677

The poison most commonly employed for suicidal purposes is carbolic acid, 88 and 75 in the two sexes, next opium and its derivatives (39 and 17), then prussic acid among males (24), and strychnia among females (12). Nearly all the deaths from suffocation are by means of hanging.

Suicide in different countries. According to figures published by Bertillon,* suicides are most frequent in Saxony, Denmark, and Switzerland, as shown in the following table:—

	Period of Observation.	Number of Annual Suicides per Million Inhabitants.
Saxony	1878–82	392
Denmark	1880–82	251
Switzerland	1878–82	239
Baden	1878–82	198
Wurtemburg	1877–81	189
France	1878–82	180
Prussia	1878–82	166
Belgium	1878–82	100
Sweden	1878–82	92
England and Wales	1878–82	75
Norway	1878–82	69
Scotland	1877–81	49
Ireland	1878–82	17

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* *Op. cit.*, p. 119.

CHAPTER XXII.

LIFE-TABLES.

LIFE-TABLES afford an accurate means of measuring the probabilities of life and death. They represent "a generation of individuals passing through time," the data on which they are founded being the number and ages of the living, and the number and ages of the dying. Dr. Farr calls the life-table a *biometer*, and speaks of it as of equal importance, in all inquiries connected with human life or sanitary improvements, with the barometer or thermometer and similar instruments employed in physical research. It is the keystone or pivot on which life assurance hinges, converting it from a mere lottery into an accurate science.

Addison, in his "Vision of Mirza," possibly writing with Halley's graduated Life-Table before him, gives the following allegory:—

> "The bridge thou seest, said he, is *Human Life;* consider it attentively. Upon a more leisurely survey of it, I found that it consisted of *threescore and ten entire arches*, with several broken arches, which, added to those that were entire, made up the number *about an hundred*. As I was counting the arches, the Genius told me that this bridge consisted at first of a *thousand arches;* but that a great flood swept away the rest, and left the bridge in the ruinous condition I now beheld it. But tell me further, said he, what thou discoverest on it. I see multitudes of people passing over it, said I, and a black cloud hanging on each end of it. As I looked more attentively, I saw several of the passengers dropping through the bridge into the great tide that flowed underneath it: and upon further examination perceived that there were innumerable trap-doors that lay concealed in the bridge which the passengers no sooner trod upon, but they fell through them into the tide, and immediately disappeared. These hidden pit-falls were set very thick at the entrance of the bridge, so that throngs of people no sooner break through the cloud, but many of them fell into them. They grew *thinner towards the middle*, but multiplied and laid closer together towards the end of the arches that

were entire. There were, indeed, some persons, but their number was very small, that continued a kind of hobbling march of the broken arches, but fell through one after another, being quite tired and spent with so long a walk."

This graphic narration of the "hidden pit-falls and trap-doors," and the "broken arches," which beset the course of human life, illustrates with beautiful simplicity the facts contained in this and the next three chapters.

Description of Life-Table. The essential portions of a life-table are the number and ages of the living and the number and ages of the dying.

(1) Suppose that we could observe a million children, all born at the same moment, and follow them throughout life, entering in a column the number who remain alive at the end of each successive year until all have died. This column is headed by the symbol l_x; where l_x represents the number who reach the precise age x.

In the second column we record the number dying before the completion of each year of life. Thus the number who die before reaching the first anniversary are placed opposite the age 0 in the table, and so on. In this way we obtain the column headed d_x; where d_x represents the number out of l_x persons attaining the precise age x, who die before reaching the age $x+1$. It is evident, therefore, that—

$$d_x = l_x - l_{x+1};$$

i.e., the number dying between the ages x and $x+1$ is equal to the difference between the numbers living at the ages x and $x+1$.

In practice it is not possible to observe a body of children throughout life in the precise manner indicated, so that other methods must be resorted to.

(2) It is not necessary to assume, as in the preceding case, that all the persons observed have been born at the same time. If we could trace any million children throughout life, however various might be the dates of their births, a life-table might be similarly constructed, if the numbers living and dying during each year of life were known.

Our national records do not lend themselves to either of these methods, but the Institute of Actuaries H.$^{\text{M.}}$ (Healthy Males) Table, which is used by the best assurance societies in this country as the basis of their calculations, is partially based on the second method; being constructed from the results of watching a large number of insured lives from the time of their insurance to death.

(3) Without tracing the history of individuals through life, we may, by taking a complete census of the population, distributed according to age and sex, obtain data for forming the column l_x. Similarly from the annual death-returns, we obtain the number dying during each year of life in a given year, and thus form the column d_x.

The methods by which the other necessary columns of a life-table are derived from these two fundamental columns will be described shortly.

(4) The method usually adopted in constructing a life-table is a modification of the last. The mortality experience of a single year may be exceptional in character. For this reason the number of persons dying within a longer period, *e.g.*, in the decennium 1881-90, and their ages at death are observed. In the same way the population out of which these deaths occurred is ascertained by calculation from a single census, or by combining the results of two census enumerations, as described hereafter. It is assumed that the rate of mortality (*i.e.*, the number of deaths *per unit of population*) for any age of life thus obtained will be applicable to other persons out of a given number started with at birth, as they successively attain the age in question. By this means results are obtained which, being wholly based on recent observations, are more correct, as indicating the present conditions affecting the duration of life, than if a million persons were watched from birth to death; for, in the latter case, the conditions which determined the rate of mortality might, before the series was available, have undergone great changes, and for practical purposes the table be almost valueless.

Dr. Farr's English Life-Table, No. 3, was based on the registered deaths in England and Wales during the seventeen years 1838–54, and on the two census enumerations of population in 1841 and 1851. Dr. Ogle's Life-Table is based on the mean population of England and Wales of the decennium 1871–80, and on the total deaths during the same decennium, and Dr. Tatham's Life-Table on the corresponding figures for 1881–90.

Method of Construction of Life-Table. It is evident that the deaths in a population, during any stated year, do not occur simultaneously either at the beginning or the end of the year, but are distributed throughout its course. It is also evident that the deaths registered at any age x will not have occurred at the precise age x, but some will have just attained the age x, whilst others will have been close on $x+1$. Now it is assumed, in the usual method of constructing a life-table, that the deaths at age x occur at equal intervals throughout the ensuing year, an assumption the error of which is infinitesimal, except for the first two years of life.

We have seen that l_x in the life-table is the number who, out of a given number born, attain the precise age x. The number l_{10}, represents the number surviving to the end of their tenth year out of a given number l_o at birth. But in a population situated as just described, persons will be found whose ages are of various intermediate periods between x and $x+1$, or in the instance taken, between ten and eleven years. If, however, we assume the deaths to be equally distributed throughout the year, the number who attain its middle will be the arithmetical mean of those commencing the year and those completing it. Thus :—

$$l_{x+\frac{1}{2}}=\tfrac{1}{2}(l_x+l_{x+1}).$$

The number who attain the middle of the tenth year of life is $l_{10\frac{1}{2}}=\frac{1}{2}(l_{10}+l_{11})$. The *mean population* thus obtained is denoted by P_x* and the deaths extracted from the registers by d_x.

If now we divide the deaths registered at any year of age (d_x) by the mean population found existing at that year of age (P_x), we shall ascertain the rate at which the population is dying in the centre of that year of age. Thus we have :—

$\frac{d_x}{P_x}=m_x$ where $m_x=$ rate of mortality per unit of population.†

We have already stated that the life-table enables us to measure the probabilities of life and of death; and, conversely, having given these probabilities, we can construct the life-table. We must first, however, see how these probabilities may be calculated from the rate of mortality (m_x) already obtained.

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* It is known as L_x in actuarial works. The above is Dr. Farr's notation.

† The ratio of deaths to mean population, or m_x, has been called by Farr the rate of mortality, and we follow his notation and system; but actuarial writers reserve the name *rate of mortality* for the probability of dying within a year (q_x). The name *central death-rate* has been given by these writers to m_x, because it represents the rate at which people are dying in the *centre* of the year x to $x+1$.

[Now the probability of an event occurring is represented by a fraction whose denominator is the number of possible events, and numerator the number of favourable events. Thus, if there are eight balls in a bag, of which three are black and five white, the probability of drawing a white ball is found as follows. The number of possible drawings is eight, inasmuch as any one of the balls may be drawn, but only five of these would be favourable. Hence the probability $=\frac{5}{8}$.

The probability of drawing a black ball $=1-\frac{5}{8}=\frac{3}{8}$.

Reverting now to the symbols and conditions of the life-table, let $l_x=$ number of persons living at the beginning of the year x, of whom l_{x+1} survive to the end of the year. The probability of anyone living to the end of the year is therefore $\frac{l_{x+1}}{l_x}$; and inasmuch as d_x die during the year, the probability of anyone dying during the year is $\frac{d_x}{l_x}$.

If we indicate by p_x the probability that a person of the precise age x will survive one full year, and by q_x the probability that the same person will die within one year, then—

$$p_x=\frac{l_{x+1}}{l_x}$$

$$q_x=\frac{d_x}{l_x}$$

$$\left.\begin{array}{l}\text{Thus the probability of}\\ \text{living through one year}\end{array}\right\}=\frac{\text{number of survivors at end of year}}{\text{number living at beginning of year}}$$

$$=\frac{l_{x+1}}{l_x}=\frac{l_x-d_x}{l_x}=p_x$$

"This may be expanded into

$$\frac{l_x-d_x}{l_x}=\frac{(l_x-\frac{1}{2}d_x)-\frac{1}{2}d_x}{(l_x-\frac{1}{2}d_x)+\frac{1}{2}d_x}$$

On the assumption of a uniform distribution of deaths, the 'mean population' of the year is obtained by deducting one half of the deaths occurring in the ensuing year from the precise number living at age x.

Hence, $l_x-\frac{1}{2}d_x$, which may also be written $\frac{1}{2}(l_x+l_{x+1})$ = the mean population for the year, which is denoted by $l_{x+\frac{1}{2}}$.

$$\text{Therefore } p_x=\frac{l_{x+\frac{1}{2}}-\frac{1}{2}d_x}{l_{x+\frac{1}{2}}+\frac{1}{2}d_x}$$

Dividing each term by $l_{x+\frac{1}{2}}$, we obtain—

$$p_x=\frac{1-\frac{1}{2}\frac{d_x}{l_{x+\frac{1}{2}}}}{1+\frac{1}{2}\frac{d_x}{l_{x+\frac{1}{2}}}}$$

But the fraction $\frac{d_x}{l_{x+\frac{1}{2}}}=\frac{\text{number dying at age } x}{\text{mean population at age } x}=m_x$ *i.e.*, the rate per unit at which people are dying in the middle of the year of age x to $x+1$; and this is the same rate as that previously arrived at by dividing the d_x of the death-registers by the p_x ascertained by enumerating the population."] Hence we have—

$$p_x=\frac{1-\frac{1}{2}m_x}{1+\frac{1}{2}m_x}=\frac{2-m_x}{2+m_x}.$$

By this formula a very simple relation is found to exist between the probabilities of life and the rate of mortality. Having, from the census returns and the death registers, obtained the ratio m_x for all values of x (*i.e.*, all ages), we can by the above formula find p_x, and thence we can, by continued multiplication, construct the life-table.

This method may be made clearer by an example. The entry in the m_x column is obtained by dividing the deaths during the year by the mean population. From the entry in this column p_x, or the probability of living one year, is obtained by the formula $p_x=\frac{2-m_x}{2+m_x}$. Thus at birth the probability of a male living one year is, by Farr's English Life-Table, $\frac{2-{\cdot}18326}{2+{\cdot}18326}={\cdot}83212$, and for each year in the series the probability of living one year is obtained in the same way.[*]

The next column (l_x) is obtained by multiplying the number living at the immediately preceding year by p_x. Thus, starting with 511,745 males at birth, the number living at the end of one year is obtained by multiplying the probability of surviving to the end of the first year by this number ($l_1=l_0\times p_1$)

$$511745\times{\cdot}83212=425358{\cdot}6.$$

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[*] These two steps can be combined, and much labour saved by the following method :—

$$\text{Since } m_x=\frac{d_x}{P_x}, \ (a) \text{ and}$$

$$p_x=\frac{2-m_x}{2+m_x}, \ (b)$$

Therefore by substituting from (a)

$$p_x=\frac{2-\frac{d_x}{P_x}}{2+\frac{d_x}{P_x}}=\frac{2P_x-d_x}{2P_x+d_x}=\frac{P_x-\frac{1}{2}d_x}{P_x+\frac{1}{2}d_x}$$

This process is shortened by logarithms as follows:—

$$\begin{array}{r}
\text{Log. } 511745 = 5{\cdot}7085692 \\
\text{Log. } {\cdot}83212 = \bar{1}{\cdot}9201860 \\
\hline
\text{Log. of product of these two} = 5{\cdot}6287552 \\
\text{Therefore product} = \ 425358{\cdot}6
\end{array}$$

The next column in the life-table is one showing the mean number living in each year of life (P_x). It is directly derived from the l_x column. Thus the mean number living in the twenty-first year $= \frac{l_{20} + l_{21}}{2}$.

The next column in the table is known as the Q_x column. The number opposite any age in this column is the sum of all the numbers in the P_x column from that age to the end of the table, *i.e.*, until all the lives become extinct; and it shows, therefore, the aggregrate number of years which the persons at each age in the table will live.

$$Q_x = P_x + P_{x+1} + P_{x+2} + \text{etc.} + P_{x+n}$$

where $x + n =$ the last age mentioned in the life-table..

From the column (Q_x), and the l_x column, the mean future lifetime (expectation of life) of any person can be obtained by the formula E_x or $\overset{\circ}{e}_x = \frac{Q_x}{l_x}$.

In the preceding remarks it has been assumed that the population and the deaths at each individual age are known. In practice this is not the case. The census reports and the annual death-returns state the population and deaths in groups of ages. Even if the number living and dying during each year of life were given, the numbers would probably, from imperfections in the returns, be less accurate than those obtained by interpolation, effected either by mathematical calculation or by the graphic method to be shortly described. The graphic method is not applicable to the first five years of life, for which a special plan of interpolation described in the following example is required.

Details of Construction of Life-Table. In the following description the figures used in the life-table for Brighton are employed as an example.

Method of ascertaining Population and Deaths for each Year of Age.—In the construction of a life-table we must have an accurate statement of

(1) The population for each year of age; and

(2) The number of deaths at each year of age occurring during the corresponding year in each sex, in order to ascertain the death-rate holding good for each year of life.

These data not being supplied in full for each year either for population or deaths, the means for interpolating the correct figures for each year of life from the figures furnished in the following table must be first given.

	Population of the Parliamentary Borough of Brighton.				Deaths in the Parliamentary Borough of Brighton, Jan. 1st, 1881, to Dec. 31st, 1890.	
	Census, 1881.		Census, 1891.			
Age.	Males.	Females.	Males.	Females.	Males.	Females.
0- . .	7233	7374	7046	7051	4569	3800
5- . .	6653	6435	7137	7169	333	301
10- . .	6158	6473	6829	7300	149	174
15- . .	5258	8069	5882	8600	229	243
20- . .	5158	8023	4967	9038	256	292
25- . .	8471	12291	9142	13894	678	709
35- . .	6260	8889	7308	10411	872	866
45- . .	4557	6698	5335	7755	1040	1034
55- . .	3174	4819	3574	5443	1104	1243
65- . .	1645	2807	2254	3451	1235	1577
75- . .	663	1041	778	1291	945	1416
85- . .	76	118	85	221	261	413
95- . .	3	4	4	5	7	22
Total all Ages	55309	73041	60341	81629	11678	12090
	128350		141970			

(1) *To ascertain the total number of lives at risk at each group of ages during the decade 1881–90.*—We must first ascertain the central population in each group by adjusting the figures in the above table to June 30th (the census being taken at the end of the first quarter of the year).

The formula is $Q' = P R^t$ where Q' = central population required; P = census population; and R = population resulting per unit per annum. R is first found from the formula $Q = P R^{10}$, as in the calculations on p. 6.

VALUE OF R FOR EACH AGE-PERIOD.

Males.			Females.		
Age.		Value of R for each Age-period.		Value of R for each Age-period.	Age.
0–	$7046 = 7233\ R^{10}$	·99738	$7051 = 7374\ R^{10}$	·99553	0–
5–	$7137 = 6653\ R^{10}$	1·00705	$7169 = 6435\ R^{10}$	1·0109	5–
10–	$6829 = 6158\ R^{10}$	1·01040	$7300 = 6473\ R^{10}$	1·0121	10–
15–	$5882 = 5258\ R^{10}$	1·01128	$8600 = 8069\ R^{10}$	1·0064	15–
20–	$4967 = 5158\ R^{10}$	·99623	$9038 = 8023\ R^{10}$	1·0120	20–
25–	$9142 = 8471\ R^{10}$	1·00765	$13894 = 12291\ R^{10}$	1·0123	25–
35–	$7308 = 6260\ R^{10}$	1·01560	$10411 = 8889\ R^{10}$	1·0159	35–
45–	$5335 = 4557\ R^{10}$	1·01590	$7755 = 6698\ R^{10}$	1·0148	45–
55–	$3574 = 3174\ R^{10}$	1·12600	$5443 = 4819\ R^{10}$	1·0123	55–
65–	$2254 = 1645\ R^{10}$	1·03200	$3451 = 2807\ R^{10}$	1·0209	65–
75–	$778 = 663\ R^{10}$	1·01610	$1291 = 1041\ R^{10}$	1·0217	75–
85–	$89 = 79\ R^{10}$	1·01200	$226 = 122\ R^{10}$	1·0636	85–

Next we find Q' the central population from $Q' = PR^{\frac{1}{4}}$ where P is the census population and R is given in the above table. Thus:—

$$Q' = 7233\ (\cdot 99738)^{\frac{1}{4}}$$

$$\log.\ 7233 = 3{\cdot}859318$$

$$\tfrac{1}{4}\log.\ \cdot 99738 = \bar{1}{\cdot}999716$$

$$\log.\ Q' = 3{\cdot}859034$$

$\therefore Q = 7228 =$ central male population, 1881, aged 0–5.

The central populations for each census year thus obtained are as follows:—

1881.			1891.		
Age.	Males.	Females.	Males.	Females.	Age.
0– . . .	7228	7366	7041	7043	0–
5– . . .	6665	6452	7150	7188	5–
10– . . .	6174	6492	6847	7322	10–
15– . . .	5273	8082	5898	8613	15–
20– . . .	5153	8047	4962	9065	20–
25– . . .	8487	12328	9159	13936	25–
35– . . .	6284	8924	7336	10452	35–
45– . . .	4575	6724	5356	7783	45–
55– . . .	3184	4834	3585	5459	55–
65– . . .	1658	2822	2272	3469	65–
75– . . .	666	1046	781	1298	75–
85– . . .	79	124	89	229	85–

Having now ascertained the central population for the two census years 1881 and 1891, we proceed to ascertain the total population for the ten years 1881–90, *i.e.*, the total number of lives subjected to a year's risk of death during this period.

The method by which the value of R has been calculated for each age-period is sufficiently indicated in the table p. 263. In calculating the total population for the years 1881–90, *i.e.*, the total number of lives at risk in the period embraced by life-table, the following method has been adopted. Employing the notation already explained, the population for each year of the decade would be denoted by P, PR, PR^2, etc. . . . PR^9. These amounts give the terms of a geometric series, of which the first term is P and common ratio is R. Hence the total population for the decade is the sum of this series, $P+PR+PR^2+\text{etc.}+PR^9$, the usual formula for which gives a sum to ten terms $=P\frac{R^{10}-1}{R-1}$

$$=\frac{PR^{10}-P}{R-1}=\frac{\text{Population, 1891 - Population, 1881}}{\text{annual increase per unit}}.$$

By means of this formula the total lives at risk can be ascertained. The number at risk at each age-period can be ascertained either (*a*) by applying the same method to each age-period, or (*b*) the method described on page 281 may be adopted. Thus in the third age-period the male population for $1891=6847$, and for $1881=6174$. The difference is 673. Also for that period $R=1{\cdot}0104$.

Therefore total population $=\frac{673}{{\cdot}0104}=64{,}712$. A similar calculation gives us the results contained in the following table for the other age-periods.

It is plain that when R is less than unity, the population for 1891 will be less than that for 1881, so that numerator and denominator of the above fraction will always have the same sign.

TOTAL NUMBER OF LIVES AT RISK IN THE TEN YEARS 1881–90, AND TOTAL NUMBER OF DEATHS DURING THE SAME PERIOD.

Age.	Number of Lives at Risk.		Deaths.		Mean Annual Death-rate for each Life at risk.	
	Male.	Female.	Male.	Female.	Male.	Female.
0– . .	71374	72259	4569	3800	·06401	·05259
5– . .	69236	67524	333	301	·00483	·00445
10– . .	64712	68595	149	174	·00230	·00253
15– . .	55408	82969	229	243	·00413	·00292
20– . .	50663	84833	256	292	·00505	·00344
25– . .	87843	130732	678	709	·00772	·00542
35– . .	67436	96101	872	866	·01294	·00901
45– . .	49119	71568	1040	1034	·02117	·01444
55– . .	33698	51020	1104	1243	·03276	·02436
65– . .	19187	30957	1235	1577	·06436	·05093
75– . .	7143	11613	945	1416	·13229	·12192
85– . .	878	1589	261	413	·29726	·25991
95– . .	34	44	7	22	·20588	·50000
Total .	576731	769803	11668	12090	·02024	·01575

NOTE.—The ages are read thus: 0 and under 5, 5 and under 10, 10 and under 15.

(2) Having now obtained a statement of the *total number of lives at risk and number of deaths* in quinquennial and decennial groups of ages, the process by which the corresponding numbers *for individual years of life* have been obtained, must be examined. There are two chief methods by which the number for the individual years of each age-period can be "interpolated."

(*a*) By the "method of finite differences" applied to the logarithms of the figures representing the population and deaths at the beginning and end of each age-period. This method, known as the *analytical*, involves complex calculations for a description of which reference may be made to p. xxv. of Dr. Farr's English Life-Table No. III. Dr. Farr's methods have been somewhat modified and improved in the calculation of the Life Table for England and Wales in 1881–90 (*Decennial Supplement of the Registrar-General*, part i.).

(*b*) By the "graphic method" here adopted. This method was described in a paper by Mr. George King, F.I.A., in the *Journal of the Institute of Actuaries*, No. cxxxi. (October, 1883), "On the Method used by Milne in the Construction of the

Carlisle Table of Mortality." In this paper Mr. King cleared up the mystery which had hung over the method pursued by Milne in the construction of the Carlisle Life-Table, and showed that the method pursued was a graphic one identical with that here described.

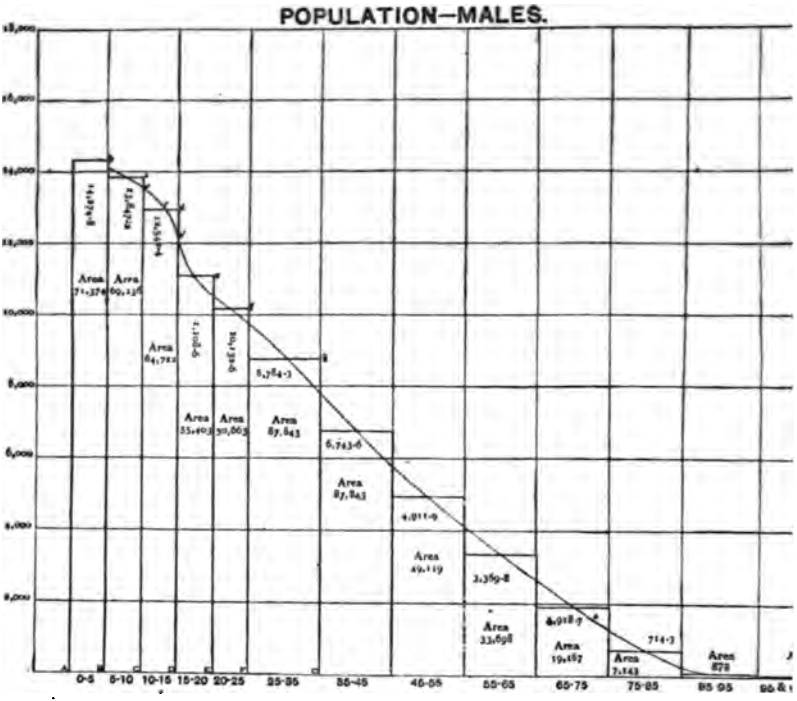

FIG. 39.

The method may be briefly described as follows: Along the abscissa line AZ (Fig. 39) mark off five equal portions, each to represent five years, for the first five quinquennial intervals of age; and let eight other equal portions, each of double length to represent ten years, succeed them for the subsequent decennial intervals of age.

At each of the points A and B erect perpendiculars to AZ, and make the perpendicular lines of such a height, in accordance with the marginal scale previously decided upon, that the parallelogram *Ab* shall equal in dimensions the population living aged 0–5. Thus in the diagram $Bb = 14274{\cdot}8$, and this when multiplied by 5, the number of years included between *A* and $B = 71374$, the number of male lives at risk at ages 0–5. Similarly $Cc = 13847{\cdot}2$, and this when multiplied by 5, gives 69,236 as the area of *Bc*. In the later groups 10 years are taken. Thus $Gg = 8784{\cdot}3$, the area of *Fg* being 87,843. Having thus plotted out the populations living at various groups of ages, the number living at each single year of life is obtained as follows:—

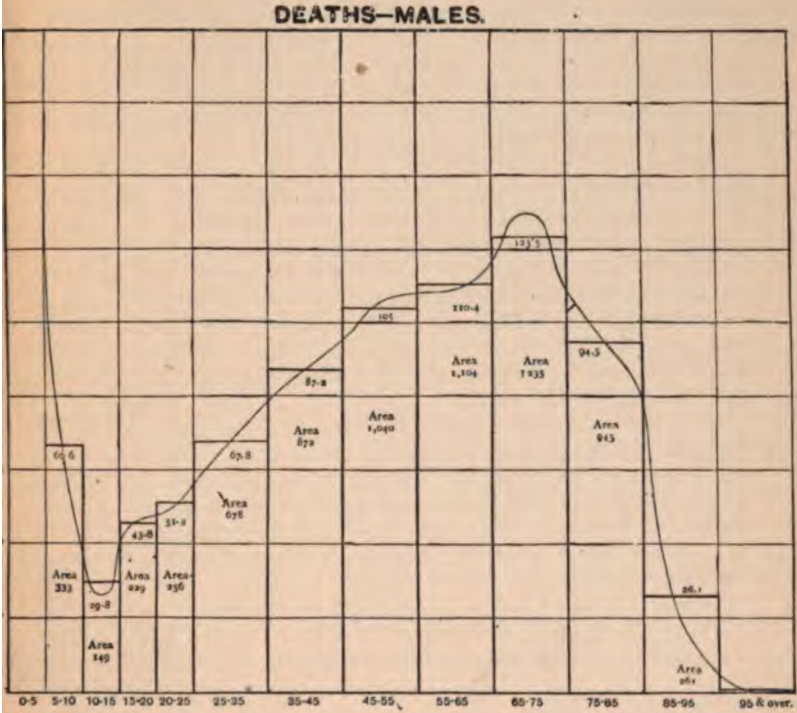

FIG. 40.

A curved line is described through the parallelograms already drawn, sweeping as easily as possible through the upper part of these parallelograms from *A* to *Z*. This curved line (1) must be as little curved as other conditions will admit of. (2) It must never change its direction abruptly so as to form an angle in its path. (3) The curved line thus described must so cut each of the parallelograms that the area included between the base line below, the corresponding portion of the two ordinates laterally, and the portion of the curved line above, shall equal the area of the parallelogram erected on the same base. Thus the area of the parallelogram Cd = the area of $Cc'd'e'D$. In other words, the area cut off is exactly equal to the area added.

If now the distances *AB*, *BC*, *CD*, *DE*, etc., along the abscissa line be divided into equal portions representing one year each, then vertical lines drawn *from the centre of each of these spaces* will give the central population for each year of age.*

The accuracy of the curve is confirmed by ascertaining that the sum of the ordinates drawn from the base line within each space to the curved line bounding the space above is equal to the area of the parallelogram drawn on the same base. Thus in Fig. 39 $Cd = 64712$ = the sum of the five ordinates, $13420 + 13220 + 13000 + 12710 + 12372$.†

This method is not only very accurate, but it serves furthermore to remove the exaggerated oscillations occurring in figures on a small scale. The tracing of the curves being effected by a purely graphical process, different draughtsmen may arrive at slightly divergent results. It is, however, impossible that any material discrepancy can thus arise if due care is exercised, and if the rules set forth above are rigidly adhered to.

Exactly the same method is pursued for the deaths occurring at each group of ages as that just described for population. The results are shown graphically in Figs. 39 and 40. The following is a sample of some of the population and death-groups before and after distribution by the graphic method.

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* In the diagram, for the sake of clearness, the divisions for single years are not shown. In practice it is best done by means of Layton's actuarial paper, which is subdivided into accurately ruled small squares, thus enabling correct measurement to be made of the perpendiculars representing the number living or the number of deaths at the centre of each year.

† It is not essential that in every case the sum of the ordinates shall exactly equal the area of the corresponding parallelogram. Occasionally it may be necessary to compensate for excess or deficiency in the neighbouring part of the curve. This is only exceptionally required in order to obtain a good curve.

TOTAL NUMBER OF LIVES AT RISK AND DEATHS FOR EACH YEAR OF AGE.

MALES.				
Age.	Population.		Deaths.	
	In Original Groups.	Distributed.	In Original Groups.	Distributed.
5		14040		100
6		13970		78
7	69236	13870	333	62
8		13740		51·5
9		13616		41·5
10		13420		32·2
11		13220		27·2
12	64712	13000	149	26·2
13		12710		27·4
14		12362		36·0
65		2520		118·5
66		2400		123·
67		2250		127·5
68		2110		129·
69	19187	1980	1235	129·5
70		1850		129·2
71		1700		128·
72		1580		124·
73		1470		116·
74		1327		110·3
95		9		3·
96	18	5	7	2
97		2		1
98		1		1
99		1		

Population aged 0–5. The graphic method just described gives accurate results for the greater part of life. The first five years of life, however, give special difficulty whatever method of calculating the central population of each of these years is adopted. This is inseparable from the defective character of the data for these years, the ages of young children being often inaccurately stated in the census returns. Although the number of children at each year of age under 5 can be ascertained from the census returns, these numbers are untrustworthy. The total number aged 0–5 may be accepted as accurate, but the distribution of this total at each age under 5 must be found by an independent method. One of the following two methods may be adopted, preferably the latter if the data are available:—

(*a*) The population under 1 year of age in any year may be taken as equal to the births from July 1st to December 31st of the preceding year *plus* the births from January 1st to June 30th in the same year, and *minus* the deaths under 1 year of age during the same half-year. Similarly the population under 1 year of age for the ten years 1881–90 may be taken to be equal to the total births from July 1st, 1880, to June 30th, 1890, *minus* the number of deaths under 1 year of age in the ten years 1881–90.

Thus, having ascertained the total male births from July 1st, 1880, to June 30th, 1890, and subtracted from the result the total number of deaths of males under 1 year of age in the ten years 1881–90, we obtain the population out of which the deaths at the age 1–2 occur during the same period. Subtracting the deaths at the age 1–2 we obtain the number out of which the deaths at the age 2–3 occur; subtracting these we obtain the population out of which the deaths at the age 3–4 occur; and subtracting these we obtain the population out of which the deaths 4–5 occur.

The sum of the five amounts thus obtained gives 76,627, which is the aggregate population at the commencement of the first five years of life. But when estimated from the census returns it is 71,374, the difference being accounted for by migration. Hence these five amounts must each be reduced in the proportion of $\frac{71374}{76627}$.

Having obtained by this means the corrected population at the beginning of each of the first five years of life, we next proceed to obtain the *mean population*, which for each of these years except the first may be taken as the geometrical mean between the population at the beginning of the year (l_x) and at its end (l_{x+1}). In other words the logarithms of the population at the beginning and end of the year are in arithmetical progression. The mean populations thus ascertained are 14,001 (1–2), 13,405 (2–3), 13,135 (3–4), and 13,580 (4–5).

The sum of these populations subtracted from 71,374 gives 17,253 as the mean population of the first year of life.

(*b*) The following is a somewhat more accurate method of obtaining the population aged 0–5, and where the necessary data are obtainable should be used. For the description of it I am indebted to Dr. Hayward.

To find the true mean numbers living and the values of p_x for the first five years of life.

For the ten years 1881–90 the data required are:

(1) The true mean numbers living for each sex at the age-period 0–5 calculated by the method previously described (or by the method to be described in the succeeding chapter).

(2) The numbers of births, males and females, for each of the years 1876–90.

(3) The numbers of deaths for each sex.

(*a*) At age 0–1 for the years 1877–90.
(*b*) ,, 1–2 ,, ,, 1878–90.
(*c*) ,, 2–3 ,, ,, 1879–90.
(*d*) ,, 3–4 ,, ,, 1880–90.

I. For the mean annual number *at birth* in the ten years there must be taken

$$\frac{\tfrac{1}{2}\text{ births in 1880} + \text{all births in 1881–89} + \tfrac{1}{2}\text{ births in 1890}}{10}$$

II. For the mean annual number *at* 1 *year of age.*

$$\frac{\begin{array}{l}\tfrac{1}{2}\text{ births in 1879} + \text{all births in 1880–88} + \tfrac{1}{2}\text{ births in 1889}\\ \text{less the number of deaths under 1 year of age in 1880–89}\end{array}}{10}$$

III. For the mean annual number *at* 2 *years of age.*

$$\frac{\begin{array}{l}\tfrac{1}{2}\text{ births in 1878} + \text{all births in 1879–87} + \tfrac{1}{2}\text{ births in 1888}\\ \text{less deaths under 1 year in 1879–88}\\ \text{and deaths 1-2 years in 1880–89}\end{array}}{10}$$

IV. For the mean annual number at 3 years of age.

$$\frac{\begin{array}{l}\tfrac{1}{2}\text{ births in 1877} + \text{all births in 1878-86} + \tfrac{1}{2}\text{ births in 1887}\\ \text{less deaths under 1 year in 1878–87}\\ \text{and ,, 1–2 years in 1879–88}\\ \text{,, ,, 2–3 ,, 1880–89}\end{array}}{10}$$

V. For the mean annual number *at* 4 *years of age.*

$$\frac{\begin{array}{l}\tfrac{1}{2}\text{ births in 1876} + \text{all births in 1877-85} + \tfrac{1}{2}\text{ births in 1886}\\ \text{less deaths under 1 year in 1877–86}\\ \text{and ,, 1-2 years in 1878–87}\\ \text{,, ,, 2–3 ,, 1879–88}\\ \text{,, ,, 3-4 ,, 1880–89}\end{array}}{10}$$

Five numbers are thus obtained which we may call

a, b, c, d, e, calling the total "N,"

$$a+b+c+d+e=N.$$

It must be carefully noted that these numbers give **not** the population numbers at all ages from 0–1, from 1–2, etc., but the numbers actually starting at birth, at 1 year of age, etc.

Now the true mean number living at the age-period 0–5 (which we may call C) which we have already calculated from the census enumerations, gives the total population *at all ages* from birth to age 5, and represents the total N *after half a year's mortality*, as well as *altered by migration.*

In order to make C correspond with N, C must be *carried back half a year* by restoring the numbers of those who have died in the first half of the years of life.

In the first year of life much more than half the mortality occurs in the first half of the year. For the other years the mortality may be considered to be evenly distributed.

Therefore C + mean annual number of those dying under 6 months of age + $\frac{\text{mean annual number of deaths at ages 1–2, 2–3, 3–4. 4–5}}{2}$ will give a value which we may call "T."

The difference of T from N will represent the alterations due to *migration.*

In order to eliminate these differences the total T must be divided up proportionately to the numbers a, b, c, d, e, which together give the total N. Thus—

$$a : N :: P_0 : T$$
$$b : N :: P_1 : T$$
$$c : N :: P_2 : T$$
$$d : N :: P_3 : T$$
$$e : N :: P_4 : T$$

We shall thus obtain a series of five numbers which we may call p_0, p_1, p_2, p_3, p_4, representing the true mean annual number living at birth, at age 1, and age 2, etc. From these numbers the p_x values for the first five years of life can be readily calculated. Thus—

$$\frac{P_0-d_0}{P_0}=P_0$$
$$\frac{P_1-d_1}{P_1}=P_1$$
$$\frac{P_2-d_2}{P_2}=P_2$$
$$\frac{P_3-d_3}{P}=P_3$$
$$\frac{P_4-d_4}{P_4}=P_4$$

Since the chance of living one year $= \dfrac{\text{number living at end of year}}{\text{number living at beginning of year}}$ and P_0 = mean annual number at birth, and d_0 = mean annual number dying from age 0 to age 1, it is obvious that the fraction $\dfrac{P_0 - d_0}{P_0}$ represents the chance of living one year from birth, etc.

This method of calculation is, of course, liable to the fallacy that the migration of children under 5 years may not be exactly proportionate for each of the first 5 years of life, but it at least gives more rational results than would be obtained by working from the obviously erroneous numbers of the census enumerations for these years.

Construction of the life-table. The number of lives at risk at each age, and the number of deaths at the corresponding ages and during the period with which the life-table deals being known, we obtain by division m_x = the rate of mortality per unit of population, better known to actuaries as the *central death-rate*, because it represents the rate at which people are dying in the *centre* of a given year.

From the m_x column, the probability that a person at each age will survive one full year (p_x) can be obtained.

The probability of living through one year $= \dfrac{\text{number of survivors at end of year}}{\text{number living at beginning of year}}$, and we have already shown that

$$p_x = \frac{2 - m_x}{2 + m_x}.$$

PROBABILITY OF LIFE AT EACH AGE, AND NUMBER OF SURVIVORS OUT OF A GIVEN NUMBER BORN.

Age.	The Probability of Living One Year. p_x	Number of Survivors at each Year of Age out of 100,000 at Birth.
	Males.	Males.
0	·84608	100000
1	·93392	84999
2	·97538	79380
3	·98144	77425
4	·98863	75987
5	·99290	75125
6	·99445	74590
7	·99554	74176
8	·99626	73845
9	·99696	73569
...	......	......
95	·63636	135
96	·66666	86
97	·60000	57
98	·60000	34
99	·60000	20
100		12
101		8
102		6
103		4
104		2
105		0

The p_x column calculated from m_x for each age having been thus obtained separately for the two sexes, we can now build up the life-table step by step.* It is usual to start with 100,000 children at birth. In Brighton during the ten years 1881–90, the births of male and female children were in the proportion of 51,195 to 48,805, making 100,000 of both sexes. The numbers 51,195 and 48,805 are, therefore, taken as the number at age 0 in the l_x column of the Brighton life-table.

Starting with 51,195 male infants at birth, the number living at the end of one year is obtained by multiplying this number by the probability of surviving to the end of the first year.

$$\text{Thus } 51{,}195 \times \cdot 84608 = 43{,}315$$
$$43{,}315 \times \cdot 93392 = 40{,}452, \text{ and so on.}$$

In order to obtain the mean expectation of life for each individual, it will evidently be necessary to ascertain the total number of years lived by the individuals under consideration, and divide the sum by the number of individuals living this total number of years. The l_x column in the table of which a portion is reprinted below (p. 275) gives the necessary data for this calculation.

Thus the 43,315 males surviving to the end of the first year of life out of 51,195 born will have each lived a complete year in the first year, or among them 43,315 years. Similarly 40,452 males will live another complete year each in the second year, or among them a further 40,452 complete years; similarly 39,456 complete years of life will be lived in the third year; 38,723 in the fourth year, and so on, until the males started with become extinct at the age of 105.

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* For a shorter method of obtaining p_x see p. 260.

BRIGHTON LIFE-TABLE.

(Based on the Mortality of the Ten Years, 1881-90.)

MALES.

Age.	Dying in each Year of Age, 0-1, 1-2, etc.	Born, and Surviving at each Age.	Sum of the Number Living, or Years of Life lived at each Age $x+1$ and upwards to the last Age in the Table.	Mean after Life-time (Expectation of Life) at each Age.
x	d_x	l_x	Σl_{x+1}	$\overset{\circ}{e}_x$
0	7880	51195	2206174	43·59
1	2863	43315	2162859	50·43
2	996	40452	2122407	52·96
3	733	39456	2082951	53·29
4	440	38723	2044228	53·29
5	272	38283	2005945	52·87
6	211	38011	1967934	52·27
7	169	37800	1930134	51·56
8	141	37631	1892503	50·78
9	114	37490	1855013	49·98
10	90	37376	1817637	49·12
11	77	37286	1780351	48·14
12	75	37209	1743142	47·35
13	80	37134	1706008	46·44
14	108	37054	1668954	45·54
	...	......	......	......
95	25	69	116	1·68
96	15	44	72	1·64
97	12	29	43	1·48
98	7	17	26	1·53
99	4	10	16	1·60
100	2	6	10	1·66
101	1	4	6	1·50
102	1	3	3	1·00
103	1	2	1	·50
104	0	1	0	
105		0		

It is evident, therefore, that the total number of complete years lived by the 51,195 males started with at birth will be $43{,}315 + 40{,}452 + 39{,}456 + 38{,}723 + \ldots\ldots\ldots 1 = 2{,}206{,}174$ years. As this number of years is lived by 51,195 males, the number of complete years lived by each male

$$= \frac{2{,}206{,}174}{51{,}195} = 43{\cdot}09 \text{ years.}$$

This result is known as the *curtate expectation of life*

We have, in the above remarks, confined our attention to the complete years of life, and have not taken into account that portion of lifetime lived by each person in the year of his death. In some instances this may only be a few days, in others nearly an entire year; but it may be assumed with a fair degree of accuracy, taking one person with another, that the duration of life in the year of death will be half a year.

If we add this half-year to the curtate expectation of life, the *Complete Expectation of Life* is obtained.

Thus the complete expectation for males at birth $= 43{\cdot}09 + 0{\cdot}5 = 43{\cdot}59$ years; at the age of 10 years $= 48{\cdot}62 + 0{\cdot}5 = 49{\cdot}12$ years. This method is accurate for most ages, but for the first year 0·5 is too much.

In the above specimens of the life-table only the complete expectation of life is printed.

The headings given in the extract from the Brighton Life-Table on p. 275 are

$$d_x,\ l_x,\ \Sigma l_{x+1}, \text{ and } \overset{\circ}{e}_x.$$

I give a sample of two other life-tables, which will throw light on some further points connected with a life-table.

LIFE-TABLE FOR ENGLAND AND WALES, BASED ON THE MORTALITY IN THE TEN YEARS 1881-90.

MALES.

Age. x	Dying in each Year of Age. d_x	Born and Surviving at each Age.* l_x	Population, or Years of Life Lived, in each Year of Age. P_x	Population, or Years of Life Lived, in and above each Year of Age. Q_x	Expectation of Life at each Age. E_x
95	162	383	302	658	1·72
96	99	221	171	356	1·61
97	58	122	93	185	1·51
98	32	64	48	91	1·42
99	17	32	24	43	1·33
100	8	15	11	19	1·24
101	4	7	5	8	1·13
102	2	3	2	3	0·98
103	1	1	1	1	0·69

INSTITUTE OF ACTUARIES H.^{M}† (HEALTHY MALES) LIFE-TABLE.

Age. x	Number Living. l_x	Number Dying. d_x	Probability of Living 1 year. p_x	Σl_{x+1}	e_x	$\frac{1}{2}d_x + l_{x+1} = \frac{1}{2}(l_x + l_{x+1}) = L_x$	$\Sigma L_x = T_x$	$\overset{\circ}{e}_x$
85	54	11	·796	166	3·07	48·5	193	3·57
86	43	9	·791	123	2·86	38·5	144·5	3·36
87	34	8	·764	89	2·62	30	106	3·12
88	26	6	·769	63	2·42	23	76	2·92
89	20	5	·750	43	2·15	17·5	53	2·65
90	15	4	·733	28	1·87	13	35·5	2·37
91	11	3	·727	17	1·55	9·5	22·5	2·05
92	8	3	·625	9	1·13	6·5	13	1·63
93	5	2	·600	4	·80	4	6·5	1·30
94	3	2	·334	1	·33	2	2·5	·83
95	1	1	·000	0		·5	·5	·50

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* Out of 509,180 started with at birth.

† Taken from an Elementary Lecture on the Theory of Life Assurance, by W. J. H. Whittall, F.I.A. (Layton).

In the second table a distinction is made between the curtate expectation of life (e_x), obtained by dividing the sum of those living at all higher ages by the number living at the beginning of any year of life, and the complete expectation of life, obtained by dividing the sum of the mean population at the same and all higher ages by the number living at the beginning of any year of life.

$$\text{Thus } e_x = \frac{\Sigma l_{x+1}}{l_x}, \text{ and}$$

$$\overset{\circ}{e}_x = \frac{\Sigma L_x}{l_x}.$$

L_x in the second table $= P_x$ in the first,
T_x ,, ,, $= Q_x$,, ,, and
$\overset{\circ}{e}_x$,, ,, $= E_x$,, ,,

$$\text{while } \frac{Q_x}{l_x} = \frac{T_x}{l_x} = \overset{\circ}{e}_x = \text{complete expectation of life.}$$

The two tables may be utilized for a study of the principles underlying the construction of a life-table and of its applications. In the first table 383 men aged 95, and in the second 54 aged 85, are observed until death. These ages are chosen for the sake of brevity, but the principles involved are exactly the same as if the life-table had commenced at birth. The relation between the curtate and the complete expectation of life is clearly seen in the second table. Thus—

$$e_{85} = \frac{166}{54} = 3{\cdot}07$$

$$\overset{\circ}{e}_{85} = \frac{166}{54} + \tfrac{1}{2} = 3{\cdot}57 \text{ years};$$

$$\text{or } \overset{\circ}{e}_{85} = \frac{193}{54} = 3{\cdot}57 \quad ,,$$

It is important to remember that the life-table represents a stationary population. A certain number are started with at birth and traced through life according to the mortality experience of a given period of years; but at every age, as deaths occur and the remainder pass on to the next year of life, their places are assumed to be taken by an equal number of the same age. Thus the 54 aged 85 in the second table become 43 aged 86, and their places are taken by another 54 who concurrently attain the age of 85.

CHAPTER XXIII.

ABBREVIATED OR "SHORT" METHODS OF CONSTRUCTING LOCAL LIFE-TABLES.

FOR the following description I am indebted to Dr. Hayward, whose life-table for the urban district of Haydock, Lancashire, comprises what is, so far as I know, the best description of the construction of a life-table by the analytical method, and contains a number of novel suggestions and practical discoveries, which are embodied in the following description:—

The labour involved in constructing a complete or "extended" life-table, that is, calculating the chance of survival (p_x) and the expectation of life (E_x) for every single year of life, even when simplified by the "graphic" method described in the preceding pages will be so considerable as to deter, perhaps, the majority of medical officers of health from undertaking it.

In view, therefore, of the great desirability that every community should possess the advantage of having available the only true measure of its vitality, it is of importance to ascertain whether by some simpler and shorter method, an approximation to the truth, sufficiently near for all practical purposes, can be attained.

Up to a certain point exactly the same work must be done for a short life-table as for a complete one.

(1) The true mean total population for the decennial period most nearly corresponding to the interval between two successive censuses must be calculated, corrections having been made, if necessary, in the census enumerations for public institutions, etc.

(2) This total must then be divided up proportionately, so as to obtain the true mean numbers living in each of the age and sex-groups usually employed in classifying population, three quinquennial age intervals being first taken, 0-5, 5-10, and 10-15, and afterwards decennial intervals to age 95.

(3) The deaths must next be most carefully enumerated and classified into groups similar to those already adopted for the population, especial care being taken to *include* all those deaths properly belonging to the district, but occurring outside it, as well as to *exclude* such deaths as may fairly be omitted as belonging to other districts, it

being borne in mind that an error of *one* in the deaths will have a many times greater effect in vitiating the calculations than an error of *ten* in the population.

(4) Separate calculations must then be made for each of the first five years of life by the method already explained. There is no short method for these years. If a simple calculation be attempted for this age-period based on the total population and total deaths at the age-period 0–5, the mean value of p_x will be much too small, the l_x number for age 5 will be correspondingly diminished, and therefore the E_x values at ages 0 and 5 will greatly err in the direction of deficiency.

To find the true mean population of a district for the ten calendar years most nearly corresponding to the interval between two successive censuses.

The simple and obvious method of taking as the mean population of a district for ten years (say 1881–90) the arithmetical mean of the two census enumerations of 1881 and 1891 is unfortunately rendered erroneous by two reasons:—

(1) On the assumption of a constant ratio of increase or decrease, the arithmetical mean must necessarily be *greater* than the true mean.

(2) The intercensal period is later by the fourth part of a year, both at its beginning and ending, than the ten calendar years most nearly corresponding.

If P be the population at the earlier census (1881), and P' the population at the later census (1891), then the rate of increase or decrease per unit or "R" $=\frac{P'}{P}$ or $P'=RP$.

The true mean population for 1881–90 may be found by dividing the arithmetical mean, that is, $\frac{RP+P^1}{2}$ by the factor

$$\frac{R^{\frac{1}{40}}\times(R+1)\times\text{Hyp. log. }R}{2(R-1)}.$$

In Part I. of the *Supplement to the Fifty-fifth Annual Report of the Registrar-General* (pp. xliv. and xlv.) is given a most valuable table (called Table P), the result of an enormous amount of labour and calculation, by which the proper factor may be easily and simply calculated for any rate of increase or decrease.

Taking the case of the population of Brighton, the total enumerated populations at the censuses of 1881 and 1891 were respectively 128,350 and 141,970.

Therefore $R=\frac{141,970}{128,350}=1\cdot1061161$.

From "Table P" the factor of correction corresponding to $R=1\cdot1061161$ is found to be $1\cdot003370+(\cdot003408-\cdot003370)\times\cdot1161=1\cdot003374$.

The true mean population, therefore,

$$=\frac{\frac{1}{2}(128,350+141,970)}{1\cdot003374}=134705\cdot5 \text{ (or 134,706).}$$

This differs by +53 from the number obtained by the method previously described on page 264.

To find the true mean annual numbers living for each of the age and sex-groups into which the population is divided.

Having given the total true mean population, this may be divided up into numbers corresponding to age and sex-groups by the method of mean proportions, which is based on the assumption that from one census to the next the proportions change uniformly.

The steps of the calculation are as follows :—

1. Calculate the proportions per million living in each of the age and sex-groups at each census. Thus, having given the facts—

(*a*) That at the census of 1881, out of a total enumerated population for Brighton of 128,350, there were living 6158 males aged from 10 to 15.

(*b*) That at the census of 1891, out of a total enumerated population of 141,970, there were living 6829 males in the same age-group. We have the proportions :—

$$6158 : 128{,}350 :: x : 1{,}000{,}000,$$

$$x = \frac{6158 \times 1{,}000{,}000}{128{,}350} = 47978{\cdot}19,$$

and

$$6829 : 141{,}970 :: x : 1{,}000{,}000,$$

$$x = \frac{6829 \times 1{,}000{,}000}{141{,}970} = 48101{\cdot}71.$$

2. Next find the proportion per million at the middle of the intercensal period, that is, five years after the earlier census.

This is done by simply taking the arithmetical mean of the two proportions already found.

Thus $\dfrac{47978{\cdot}19 + 48101{\cdot}71}{2} = 48039{\cdot}95.$

3. Take the difference between this last found value and the proportion at the earlier census. This will give the change of proportion in five years.

Thus $48039{\cdot}95 - 47978{\cdot}19 = +61{\cdot}76.$

4. Now we only want $\frac{19}{20}$ of this last value for the change in proportion for four and three-quarter years (corresponding to $\frac{19}{40}$ of the total change in ten years).

Therefore, as the change in proportion has been in the direction of *increase*, the required mean proportion per million at the period of four and three-quarter years after the earlier census is found by *subtracting* $\frac{1}{20}$ of the change in five years from the value corresponding to the middle of the intercensal period.

Thus $48039{\cdot}95 - \dfrac{61{\cdot}76}{20} = 48036{\cdot}86.$

If the change in proportion had been in the direction of *decrease*, the value $\dfrac{61{\cdot}76}{20}$ would have had to be *added*.

5. Finally, we have the proportion :—

$$48036{\cdot}86 : 1{,}000{,}000 :: x : 134{,}706,$$

$$x = \frac{48036{\cdot}86 \times 134{,}706}{1{,}000{,}000} = 6470{\cdot}8.$$

Supposing the work completed up to this point, and it is desired to take a "royal road" beyond, the short method hitherto usually employed has been that invented by the late Dr. W. Farr, and described by him twenty-three years ago in the *Supplement to the Thirty-fifth Annual Report of the Registrar-General.*

The general principle of this method is to calculate from the numbers of population and deaths for a 5-yearly or 10-yearly age-period, the mean value of p_x; that is, the mean chance of surviving one year during the age-period, and then to use five or ten times this value, respectively, in calculating the next stage in the l_x column.

In actual experience, as well as in the mathematical calculations of a complete life-table, it will, of course, be obvious that (after age 15) the chance of survival will be greater in the first year of the age-period, and less in the last year, than the mean value so found.

A very simple calculation, involving only an elementary knowledge of the use of logarithms, suffices to determine these mean values of p_x.

Having given the total mean number living, and the total number dying for a given age-period, the mean chance of living one year during the age-period is found by the fraction—

$$\frac{\text{population} - \frac{1}{2}\text{ deaths}}{\text{population} + \frac{1}{2}\text{ deaths}} = p_x.$$

Thus, having given the facts (1) that for the age-period 5–10, the mean annual number of males living in Brighton was 6923·6, and (2) the mean annual number of deaths was 33·3,

$$p_x = \frac{6923{\cdot}6 - 16{\cdot}65}{6923{\cdot}6 + 16{\cdot}65}$$

and log. $p_x = \text{log. } 6906{\cdot}95 - \text{log. } 6940{\cdot}25 = 3{\cdot}8392864 - 3{\cdot}8413752 = \bar{1}{\cdot}9979112$, therefore $p_x = {\cdot}99520$.

This value only differs from the mean value of the separate p_x values determined by the complete life-table by $-{\cdot}00002$.

Again having given the facts for the age-period 75–85, (1) that the mean annual number of males living$=714{\cdot}3$; (2) that the mean annual number of deaths$=94{\cdot}5$,

$$p_x = \frac{714{\cdot}3 - 47{\cdot}25}{714{\cdot}3 + 47{\cdot}25} = \frac{667{\cdot}05}{761{\cdot}55}$$

$$= \frac{2{\cdot}8241584}{-2{\cdot}8816984} = \bar{1}{\cdot}9424600 = {\cdot}87591.$$

The mean value of the separate values of p_x for the age-period in the complete life-table$={\cdot}85862$, so that the value determined by the short method differs from this by $+{\cdot}01729$.

If the mean values of p_x for each of the decennial age-periods after age 25, arrived at by the short method, be compared with the corresponding values determined in the complete life-table, it will be found that there are increasing differences in the direction of excess, as is shown in the following tabular statement:—

Age-periods.	Mean Values of p_x for Brighton (males).		Differences.
	In the Extended Life-table.	By the Short Method.	
5–10	·99522	·99520	– ·00002
10–15	·99769	·99770	+ ·00001
15–25	·99545	·99544	– ·00001
25–35	·99226	·99231	+ ·00005
35–45	·98693	·98715	+ ·00022
45–55	·97872	·97905	+ ·00033
55–65	·96719	·96777	+ ·00058
65–75	·93553	·93764	+ ·00211
75–85	·85862	·87591	+ ·01729
85–95	·71973	·74121	+ ·02148
95–		·81333	

It will be noted that the value of p_x for the age of 95 and upwards, as arrived at from the data, is much greater than that for the age-period 85–95.

This is a manifest anomaly, and cannot be in accordance with the actual facts. There is so much mis-statement of age, and the numbers dealt with are so small, that it is better, in order to obtain a working value of p_{95}, to discard the actual data and to make a calculation based on the four or five preceding values of p_x.

The following method will give the required value :—

CALCULATION OF p_{95} FOR BRIGHTON (MALES).

Let the logarithms of the mean values of p_x for the four preceding decennial age-periods be set down in a column, and let their differences be taken until the third and last difference is obtained. Thus—

	First Differences.	Second Differences.	Third Difference.
$\log. p_{55-65}=\bar{1}\cdot9857705$ –	·0137342 –	·0158421 –	·0271063
$\log. p_{65-75}=\bar{1}\cdot9720363$ –	·0295763 –	·0429484	
$\log. p_{75-85}=\bar{1}\cdot9424600$ –	·0725247		
$\log. p_{85-95}=\bar{1}\cdot8699353$ –			

If these differences be continued downwards, it is obvious that a fifth equidistant term can be obtained. Thus—

$$\log. p_{95-}=\bar{1}\ 8699353-(\cdot0725247+\cdot0429484+\cdot0271063)=\bar{1}\cdot7273559.$$

$$\text{Therefore } p_{95-}=\cdot53377.$$

From the series of mean values of p_x for the age-periods from age 5 onwards, it is now possible to continue the calculations of l_x from the l_5 value, already calculated in the complete life-table, and the results arrived at are as follows :—

Values of E_x obtained for Brighton (Males) by Dr. Farr's "Short" Method, compared with the Corresponding Values in the Extended Life-Table, denoted respectively by "*B*" and "*A*."

Age x.	*B*.	*A*.	Differences of *B* from *A*.
0	43·84	43·59	+ ·25
5	53·25	52·87	+ ·38
10	49·49	49·12	+ ·37
15	45·03	44·67	+ ·36
25	36·91	36·51	+ ·40
35	29·46	29·02	+ ·44
45	22·84	22·36	+ ·48
55	17·05	16·48	+ ·57
65	11·72	10·96	+ ·76
75	7·80	6·64	+1·16
85	5·50	3·33	+2·17
95	5·00	1·68	+3·32

This method, while at the earlier ages giving a moderately close approximation to the results of a complete life-table, can scarcely be considered at the later ages as entirely satisfactory.

If we analyze the reasons for the discrepancies in the direction of excess of the values of E_x obtained, they are found to be twofold.

(1) The progressively increasing values of p_x over the mean values of the complete life-table already demonstrated. The values of l_x are therefore increased, and the years of life calculated from l_x and l_{x+10} are increased in greater proportion than l_x is increased.

(2) But even if we were able to get the mean values of p_x by the short method to *exactly* correspond with those of the complete life-table, and, therefore, the values of l_x to be identical, the calculation of the years of life at 10-yearly intervals would give errors in excess over the sums of the separate yearly values, and therefore the values of E_x would be too great.

However, by a simple modification of Dr. Farr's short method, Dr. Hayward found that very close approximations to the true E_x values of a complete life-table can be obtained. His results were embodied, in the first instance, in the life-table for Haydock, and are reproduced here by his permission and assistance.

Going back to the point at which we had the data, (1) the number of survivors at age five already calculated, (2) the mean values of p_x for the various age-periods, the years of life lived in each decennial age-period were calculated by Dr. Farr's method thus:—

$$\frac{l_x + l_{x+10}}{2} \times 10 = \text{years of life.}$$

To take a numerical example. Suppose that at age 75 we have survivors numbering 16,000, and that the mean value of p_x for the age-period 75–85 has been found to be ·87055, then the number of survivors at age 85 will be $16{,}000 \times (\cdot 87055)^{10} = 4000$, and the years of life will be $\frac{16{,}000 + 4000}{2} \times 10 = 100{,}000$.

Now if the calculation be made in *two* stages instead of one, the result will come out as follows:—

$$(1)\ 16{,}000 \times (\cdot 87055)^5 = 8000;$$
$$(2)\ 8000 \times (\cdot 87055)^5 = 4000,$$

and the years of life $= \left(\frac{16{,}000 + 8000}{2} + \frac{8000 + 4000}{2}\right) \times 5 = 90{,}000.$

Again, the calculation may be made in *four* stages:—

$(1)\ 16{,}000 \times (\cdot 87055)^{2\frac{1}{2}} = 11{,}314;$ $(2)\ 11{,}314 \times (\cdot 87055)^{2\frac{1}{2}} = 8000;$
$(3)\ 8000 \times (\cdot 87055)^{2\frac{1}{2}} = 5656;$ $(4)\ 5656 \times (\cdot 87055)^{2\frac{1}{2}} = 4000,$

and the years of life $=$

$$\left(\frac{16{,}000 + 11{,}314}{2} + \frac{11{,}314 + 8000}{2} + \frac{8000 + 5656}{2} + \frac{5656 + 4000}{2}\right)$$

$\times 2\frac{1}{2} = 87{,}425.$

Similarly the calculation may be made in *ten* stages, with the result of reducing the estimated years of life to 86,701.

It is thus obvious that by the simple device of reducing the calculated years of life by increasing the number of stages in the calculation of l_{x+10} from l_x, the possibility is presented of obtaining values of E_x more nearly approaching the true values.

Dr. Hayward has made it a matter of experiment to find the most simple and most accurate application of this idea. Starting again with the l_5 number in the complete life-table, and with the mean values of p_x calculated by the short method, the following rules have been adopted:—

(1) For each of the decennial age-periods for age 15 to age 85 the calculation has been made in *two* stages.

(2) For the age-period 85–95 *four* stages have been used. For most of the other Life-tables in which the method has been tried a more accurate result has been obtained by making the calculation of the age-period 75–85 also in *four* stages.

(3) After age 95 the calculation has been made in *yearly* stages.

The results obtained are shown in the following table:—

CALCULATED VALUES OF E_x FOR BRIGHTON (MALES), "*C*" COMPARED WITH THE CORRESPONDING VALUES "*A*" OF THE COMPLETE LIFE-TABLE.

Age x.	*C*.	*A*.	Difference of *C* from *A*.
0	43·53	43·59	− ·06
5	52·84	52·87	− ·03
10	49·07	49·12	− ·05
15	44·61	44·67	− ·06
25	36·46	36·51	− ·05
35	28·98	29·02	− ·04
45	22·30	22·36	− ·06
55	16·42	16·48	− ·06
65	10·93	10·96	− ·03
75	6·65	6·64	+ ·01
85	3·40	3·33	+ ·07
95	1·63	1·68	− ·05

It is therefore evident that by this short and easy method values of E_x are to be obtained at decennial age-intervals *approaching the true values with remarkable exactitude.*

It must be carefully noted that this method does not give accurate values of E_x for the intermediate even ages, 20, 30, etc. The intermediate values of l_{x+5} obtained are of no use, except as helping to reckon the years of life lived in the interval between age x and age $x+10$.

From these decennial values of E_x it is possible to obtain the intermediate quinquennial values by a simple method of "interpolation."

(1) Where there are four equidistant terms of a series to work with, as for instance E_{15}, E_{25}, E_{35}, and E_{45}, *from ten times the sum of the two middle terms subtract the sum of all four terms, and divide the remainder by* 16, *the result is the centre term* E_{30} *required.*

$$\text{Thus } E_{30}=\frac{10(E_{25}+E_{35})-(E_{15}+E_{25}+E_{35}+E_{45})}{16}.$$

(2) Where at the top or bottom of the series there are only three terms to work with, together with a fourth term already interpolated by the preceding formula, *to one-fourth of the sum of the two outside terms add one and a half times the inside term, and subtract from the sum the value of the term already interpolated.*

$$\text{Thus } E_{90}=\frac{E_{75}+E_{95}}{4}+1\tfrac{1}{2}\,E_{85}-E_{80},$$

$$\text{and } E_{20}=\frac{E_{15}+E_{35}}{4}+1\tfrac{1}{2}\,E_{25}-E_{30}.$$

These formulæ are to be easily deduced from "Lagrange's Theorem."

It is useless to attempt to obtain values of E_x at the intermediate even ages by taking the enumerated population and recorded deaths at 5-yearly intervals, and calculating the p_x values from these numbers. The results are so uneven as to be quite unreliable.

It is a work of considerable labour to interpolate intermediate quinquennial values in the numbers of population and deaths by formulæ corresponding to those above given applied to the logarithms of the numbers representing population and deaths at age x and upwards, whereas by reserving the interpolation until the last stage in the E_x numbers, the labour is very much less, *and the results equal in accuracy those already obtained for the odd ages.*

Those who may desire to have a more detailed explanation of this method, and to see its results as applied to other life-tables, may refer to Dr. Hayward's paper "On Local Life-Tables by Short Methods," in *Public Health*, vol. x. no. x., July, 1898.

History of Life-Tables. The earliest English Life-Table was constructed by **Halley,** the English astronomer, in the second half of the seventeenth century. It was calculated on the deaths in the city of

Breslau in the years 1687–1691. Males and females are not distinguished in it, nor in the Northampton and Carlisle Tables.

De Moivre's hypothesis was suggested by Halley's Breslau Tables. He concluded that the hypothesis that out of eighty-six persons born one dies every year till all are extinct, would very nearly represent the mortality of the greater part of life, and that in the calculation of annuities its errors would nearly compensate one another. Tables formed on this hypothesis, as well as on the Northampton Table to be next considered, overstate the mortality of young adults. The consequence is, that in life assurances calculated on the results of De Moivre's and Price's Tables, the young are made to pay for the old, and injustice is done to those who insure comparatively early in life.

The first life-table used for the purpose of determining the rate of premium to be paid for life assurance was Dr. Price's **Northampton Table**, which was used by the Equitable Office on its establishment in 1762. Like Halley's Table, owing to the want of proper materials, the Northampton Table was not constructed by a comparison of the *deaths and the living at each age*, but from *the deaths alone*. Tables constructed on this latter plan are only correct when the population in which the deaths occur remains stationary; *i.e.*, when the births and deaths are equal in number, and there is no disturbing migration. Dr. Price was under the misapprehension that the population of Northampton was stationary, judging by the number of infantile baptisms. But at the time the data for this table were recorded, there were a large number of Baptists in Northampton, who repudiated infantile baptism. The consequence of this oversight was that Dr. Price assumed the mean duration of life to be twenty-four years, when it was really about thirty years. Unfortunately his table was made the basis for the government annuity schemes; and the same error which gave the insurance offices one-third too high premiums induced the government to grant annuities by one-third too large for the price charged, resulting in a loss to the public funds of about two millions of money before the error was corrected.

Dr. Price also constructed a correct life-table from the population and deaths in Sweden, "which was the first national life-table ever made, and redounds much more to his fame than the Northampton Table" (Farr).

The **Carlisle Table** was formed by Mr. Milne, from the observations of Dr. Heysham, upon the mortality of that town in the years 1779–89, and two enumerations of its population in 1779 and 1787. At the time it was constructed it showed results too favourable for the whole country; but owing to the decrease of mortality which followed, it became more accurate. De Morgan gives the following expression, based on the Carlisle Table, as representing more nearly the mortality from the age of 15 to that of 65 than does De Moivre's hypothesis. Of every one hundred persons aged 15, one dies every year till the age of 65. Or if we take the mean after-lifetime, according to the Carlisle

Table, between the ages of 10 and 60, for rough purposes it may be said: Of persons aged 10 years, the mean after-lifetime is 49 years, with a diminution of 7 years for every 10 years elapsed; thus, of persons aged 20 years, the mean after-lifetime is 49 - 7 = 42 years; at 30 years of age, 35 years, and so on. The mean after-lifetime, according to different life-tables, is shown in the table at p. 299.

Details respecting the **Amicable Society's Table** and the **Equitable Table,** the latter of which gives the experience of the Equitable Society from 1762 to 1829, of 5000 lives; the **Government Tables,** which give the experience of 22,000 government annuitants; or the **Experience Table,** based on the recorded experience of seventeen life offices and 83,905 lives, cannot be given here. We must pass on to Dr. Farr's Life-Tables, which are based on the census and death-returns of the whole of England and Wales, and not of insured and therefore selected lives like the preceding.

English Life-Table, No. 1. Dr. Farr, believing that nothing short of a table based on the returns of the entire kingdom would be satisfactory, constructed his No. 1 Table, based on the census returns of 1841 and the deaths of the same year (*Registrar General's Fifth Report*). Thinking, however, that the records of *one year's deaths* might be open to challenge owing to the short time embraced in them, he constructed the **English Life-Table, No. 2.** This is founded on the census enumerations of 1831 and 1841, and the deaths of seven years are taken; viz., those in 1841 and the three previous and three subsequent years. It is thus based upon the recorded ages of 13,896,797 + 15,914,148 = 29,810,945 persons, and on the registered deaths of 2,436,648 persons.

The difference between these two English Life-Tables, as shown by the number of survivors at various ages, and by the mean after-lifetime, is slight.

The English Life-Table, No. 3, constructed by Dr. Farr, was based on the census enumerations of 1841 and 1851, and upon the 6,470,720 deaths registered in the seventeen years 1838-54.

For a detailed description of the methods of construction of this table, the reader is referred to the English Life-Table, by Dr. W. Farr: Longman and Co., 1864.

The near agreement between the results obtained by these three English Life-Tables is very remarkable, and shows that, spite of annual fluctuations, there was a fairly stationary mortality during 1838-54, which, we may add, continued up to the year 1871. The latter fact led Dr. Farr to abandon his intention of constructing a fourth English Life-Table down to 1872.

The **Healthy Districts Life-Table** was constructed by Dr. Farr on the basis of the mortality during the five years 1849-53, in sixty-three selected English districts which showed, during the decennium 1841-50, a mean annual death-rate not exceeding 17 per 1000 persons living. As pointed out by Dr. Farr, it expresses "very accurately the actual duration of life among the clergy and other classes of the community living under favourable circumstances." It represented also a standard of healthiness already attained, and was therefore useful for purposes of comparison. This table is printed in the *Thirty-third Annual Report of the Registrar-General.*

The **Upper Class Experience Table** was constructed by Mr. C. Ansell from data collected by him as to men of the upper and professional classes, and given in his *Statistics of Families in the Upper and Professional Classes.*

The **Healthy Males Table** of the Institute of Actuaries is based on the experience of the principal insurance offices in regard to insured, and therefore exceptionally healthy, lives.

The **Clerical Experience Table** is based on data respecting over 5000 clergymen living between 1760 and 1860.

The **English Life-Table** by Dr. Ogle, published in the *Supplement to the Thirty-fifth Annual Report of the Registrar-General,* deals with the national experience in the decennium 1871–80, and that by Dr. Tatham with that for 1881–90.

The **New Healthy Districts Life-Table,** by Dr. Tatham, forms a valuable index of sanitary progress in recent years. Thus whereas in 1841–50, the period dealt with by Dr. Farr's Healthy Districts Life-Table, "less than 6 per cent. of the total population lived in districts the crude death-rates in which were below 17·5 per 1000; in 1881–90, on the other hand, no less than 25 per cent. of the population lived in districts the crude death-rates in which fell below 17·5 per 1000, and 4½ per cent. in districts the crude death-rates in which did not reach 15·0 per 1000." There are differences of age and sex-constitution to be allowed for; which has been done in the last decennial supplement, by obtaining death-rates in a standard population. When this has been done, it is found that about one-sixth of the entire population, or 4,606,503 persons, had death-rates below 15 per 1000 in 1881–90. This new table is therefore calculated on 46 million years of life, a basis more than nine times as great as that of the older table.

CHAPTER XXIV.

METHODS OF CALCULATING THE DURATION OF LIFE.

THE duration of life is the problem with which vital statistics are largely occupied; while preventive medicine is largely concerned with endeavours towards the attainment of Isaiah's ideal (chap. lxv. 20): "There shall be no more thence an infant of days, nor an old man that hath not filled his days: for the child shall die an hundred years old." Although nothing is more uncertain than the duration of life, when the maxim is applied to the individual, there are, as Babbage has put it, "few things less subject to fluctuation than the duration of life in a multitude of individuals." It is on this principle that annuities and life assurance can be made the subject of definite and exact calculations, the final results being found to vary within but narrow limits.

Several tests are employed to measure the duration of human life, and we are concerned in this chapter to determine their precise value and the relationship existing between them.

Those most commonly employed are:—

(1) The mean age at death;
(2) The probable duration of life;
(3) The mean duration of life;
(4) The expectation of life, or mean after-lifetime;
(5) The number living out of which one dies annually.

In a life-table or normal population, when all the lives are included in the calculation, the mean age at death, the expectation of life, and the number out of which one dies annually, are numerically identical. The thorough comprehension of this point will go far towards elucidating the relationship between the five above means of testing the duration of life.

In the construction of the life-table we have seen (p. 274) that when the sum of the numbers living at all the ages higher than a given age x is taken, *each life is counted once for every complete year it survives after the age x.* The sum total represents the total number of complete years of life lived by the persons who enter upon the year of life x. If this sum be divided by the number who, according to the life-table, enter upon this year of life, the quotient will be the individual expectation of life at the age x, so far as complete years of life are concerned. (If we add to this amount half a year as representing the average duration of existence during the x^{th} year of life for those who die during that year, we obtain the complete expectation of life.) But the above sum (of the numbers living at all the ages above x) is also the number constantly living in the place above the age x. Thus in the Brighton Life-Table out of 51,195 male children at birth, sixty-nine are left at the age of 95 years, and the sum of the number living at all higher ages is $44+29+17+10+6+4+3+2+1=116$ years. But $\frac{116}{69}=1{\cdot}68=$ the individual curtate expectation at the age of 95. The number 116 also represents the sum of the number of males constantly living in Brighton at ages above 95 out of 51,195 male children born, who have been traced through life in accordance with the mortality experience in 1881–90. In other words, it represents the entire population aged over 95. Inasmuch as these all die at this or some subsequent age, if we divide the entire population 116 by the number 69 who are living at the age 95, we obtain the number out of which one dies annually, which is identical with the expectation of life.

In the preceding illustration it has been shown that the number out of which one dies annually and the expectation of life are identical for the age 95. It can similarly be shown that they are identical at birth or any subsequent age.

At birth the mean age at death is also identical with the mean expectation of life, as may be ascertained by the somewhat laborious method of dividing the sum obtained by adding together the total ages of the dying in each year of life, and finding this sum by the total number of deaths.

Thus in a stationary or life-table population the following represent identical quantities:—

Mean age at death of persons at all ages

$$= \frac{\text{Sum of ages at death}}{\text{Total No. of deaths}}$$

$$= \frac{\text{Number of population}}{\text{No. of deaths in one year}}$$

$$= \left.\begin{array}{l} \text{Mean duration of life} \\ \text{or, Mean expectation of life} \\ \text{or, Mean after-lifetime} \end{array}\right\} \text{at birth.}$$

In Dr. Farr's Life-Table population, the persons become reduced to one-half in 45 years = the probable lifetime; the mean after-lifetime = 40·9 years, or very nearly 41 years; and this = the mean age at death. In such a life-table population to forty-one persons living there is one birth and one death annually; the rate of mortality is one in forty-one; and forty-one is the mean after-lifetime or expectation of life.

Mean Age at Death $= \frac{\text{sum of ages at death}}{\text{number of deaths}}$. Thus, if five persons die at the ages 10, 20, 30, 40, 50, their mean age at death $= \frac{10+20+30+40+50}{5} = 30$ years; and if a second group of five die at the age of 25, 30, 45, 50, 70 respectively, their mean age at death will be $\frac{25+30+45+50+70}{5} = 44$ years. Assuming that these two groups of persons were exposed during life to similar influences, the question arises, Would the mean age at death of the two groups form a safe standard of comparison between them? It should be noted, to begin with, that the number of persons in the instances quoted is very small, and cannot therefore form a trustworthy basis for comparison. But even if each group embraced a large number of persons, erroneous conclusions would certainly be drawn, as the age-constitution of the two groups is so different. In a normal or life-table population, the mean age at death is, as already seen, the same as the expectation of life at birth. But in a population like that of England and Wales, where the births constantly exceed the deaths, and the population is an increasing one, the mean age at death is necessarily lowered by the large proportion of deaths of young children. On the other hand, when a high birth-rate continues for a series of years, there being added every year to the population more than are taken from it by death and migration, there results an excessive proportion of persons between the ages of 5 and 55, during which period of life the death-rate is below the average death-rate for all ages. Consequently we have the following facts for England and Wales in 1881–90 :—

	England and Wales.		
	Males.	Females.	Persons.
Mortality	1 in 49	1 in 55	1 in 52
Mean Age at Death*	30·5	33·9	32·1
Mean Expectation of Life at Birth .	43·7	47·2	45·4

* Calculated approximately by Dr. Hayward (Haydock Life-Table, p. 32).

The proportional mortality, and the mean age at death, are seen to be lowered by the continued excess of births over deaths, and are not equal to the expectation of life, as they would be in a life-table population.

In *contrasting different nations* the mean age at death is a most fallacious test, owing to variations in birth-rate and in migration of population. This is shown by the following table from Farr's *Vital Statistics*, p. 473 :—

	Mortality ; or, One Death	Mean Age at Death.	Mean After-life-time or Expecta- of Life.
England (1841) . .	In 46 living	29 years	41 years
France ,, . .	,, 42 ,,	34 ,,	40 ,, ?
Sweden ,, . .	,, 41 ,,	31 ,,	39 ,,
Metropolis ,, . .	,, 41 ,,	29 ,,	37 ,,
Liverpool ,, . .	,, 30 ,,	21 ,,	26 ,,
Surrey (extra-Metropolitan)	,, 52 ,,	34 ,,	45 ,,

It will be observed that in England, where the mean age at death was lowest of three countries in 1841, the mortality was also lowest, but the true expectation of life, as deduced from a life-table, was highest; whereas if the mean age at death were a trustworthy test of the duration of life, a low mean age at death ought to be accompanied by a high mortality.

It may be inferred from the above table that the mortality (number out of which one death occurs), although it does not pretend to express the true mean expectation of life, gives a much nearer approximation to it than does the mean age at death. This will be at once seen if the mortality and expectation of life columns in the preceding table be arranged side by side, for they coincide in position in every instance, unlike the mean age at death, which gives very variable indications.

(1) In contrasting the *same country at different periods*, similar fallacies may arise. Thus 49 per cent. of the total population was under twenty in England in 1821, but in 1891 only 45 per cent., which would have considerable effect on the mean age at death.

(2) We have seen that *urban populations* consist in a much larger proportion of persons under forty than do *rural* populations. Similar differences may exist between the several districts of large cities, and correction for different age-constitution of populations may sometimes reverse the apparent position of the populations under comparison.

(3) In the comparison of different *classes of society*, and those engaged in different *occupations*, serious errors have arisen by the use of this test to determine their relative vitality. It would be absurd, for instance, to draw any inferences from a comparison of the mean ages at death of bishops and curates, as men do not usually become bishops till they have passed the middle period of life. Similarly in comparing the gentry with tradesmen. Many gentry are retired tradesmen, and their mean age at death is therefore higher than that of tradesmen. A Socialist leader in 1890 stated that the mean age at death of workmen was 29–30 years, of the well-to-do classes 55–60 years. This statement does not shed any light on the relative vitality of the two classes under comparison. It simply shows that the Trade Union Societies, from which some of the above figures were derived, consisted largely of young men, whose age at death, if they died at all, must necessarily be lower than that of the well-to-do classes, consisting as they do in a large measure of persons retired from active work.

The acceptance of the mean age at death as a test of the duration of life is a fragment of the error involved in the construction of a life-table from the deaths alone, as in Dr. Price's Northampton Table (see p. 287).

Effect of Birth-rate upon the Mean Age at Death. We have already seen that in a stationary population unaffected by migration, in which the births equal the number of deaths, the expectation of life at birth is identical with the mean age at death, and with the number of the population out of which one death annually occurs. Inasmuch as the births and deaths are equal in number, the mean age at death is also equal to the number out of which one annual birth occurs. In a non-stationary population the state of matters is altogether different.

The late Sir B. W. Richardson claimed for the inhabitants of his "Hygeiopolis" that their death-rate would be reduced to five per 1000. It was soon afterwards asserted in the *Times* that this would imply a mean duration of life (using the term in the sense of mean age at death) of 200 years, and that *a fortiori* Sir B. W. Richardson's anticipations were absurd. It is only, however, where the population is stationary that the mean age at death would be 200 years; and under existing conditions the above anticipation was not quite so absurd as it appeared.

Dr. Bristowe, in the St. Thomas's Hospital Report for 1876, worked out the influence of variations in the birth and death-rate on the mean age at death. He assumed the simplest condition of things, viz., that in each case the birth-rate and death-rate continue uniform from year to year; that no immigration or emigration occurs; and that every individual born into the population attains the mean age, or, in other words, all the inhabitants die at the same age. Under these conditions, where the births exceed the deaths, the population, births and deaths, all increase from year to year by geometrical progression.

Let number of population from which we start $=1$, and $b=$ birth-rate, and $d=$ death-rate of this unit, and $r=$ its annual increase; *i.e.*, $r=b-d$.

Then the following three series will represent the annual growth of the population, of the births, and of the deaths respectively.

	Population.	Births.	Deaths.
1st Year	1	b	d
2nd ,, ...	$(1+r)$	$b(1+r)$	$d(1+r)$
3rd ,, ...	$(1+r)^2$	$b(1+r)^2$	$d(1+r)^2$
4th ,, ...	$(1+r)^3$	$b(1+r)^3$	$d(1+r)^3$
*n*th ,, ...	$(1+r)^{n-1}$	$b(1+r)^{n-1}$	$d(1+r)^{n-1}$

According to the hypothesis with which we started, all the persons born in any one year die together in the course of some subsequent year, and the number of that year, reckoning from the time of births, is the mean age at death. It is evident, therefore, that if we can ascertain the number of that term in which

$d(1+r)^{n-1}=b$, the value of the index $n-1$ will represent the mean age at death. Let x = the value of the unknown index.

Now from $d(1+r)^x=b$, we obtain

$$(1+r)^x=\frac{b}{d},$$

and taking the log. of each side of this equation,

$$x \log. (1+r)=\log. b-\log. d,$$

$$\therefore x=\frac{\log. b-\log. d}{\log. (1+r)},$$

from which equation the value of x is easily determined.

The assumptions made as to the constitution of the population and their uniform age at death are absent in experience; and the formula cannot be applied under the actual conditions of any known community with advantage. It is useful, however, as indicating that a high death-rate is not incompatible with longevity; and that a low death-rate, apart from any consideration of the birth-rate, does not necessarily imply a long-lived population.

Mean Length of Life. The term "mean length of life" has been employed by Professor Corfield to indicate the figure obtained by the application of the preceding formula to the birth-rate and death-rate of the parish of St. George, Hanover Square, London. The formula shows a much more favourable result for this parish than for many other parts of London. For the reasons given above this test cannot be considered to possess any value. The birth-rate can only influence the death-rate by altering the proportionate number of persons living at different ages, and therefore exposed to the varying chances of death associated with these ages. If there is a large excess of persons living at ages under 5, the "mean length of life" will be low, because about 6 per cent. of these children will die. If there happen to be a large excess of persons living at the opposite extreme of age, the "mean length of life" will be high. Consequently there are only two means of accurate comparison of the vital statistics of different populations. (*a*) The best is the comparison of expectations of life derived from a life-table. (*b*) The next best is the statement of the deaths at each age-group in proportion to the number living at the corresponding age-group.

Dr. Rumsey urged that returns should be made of the **mean age of the living** $=\frac{\text{sum of ages of population at census}}{\text{number of population}}$ as a corrective of the fallacies connected with the mean age at death. He adds it is now "clear that the average duration of the lives of those who *die* in any place or country does not imply the average age of those who *live* there, any more than it means their average 'expectation of life.'" He gives the following example, taken from the experience of the metropolis a quarter of a century before the date of his remarks: "Paradoxical as it may seem to the uninitiated, one out of forty-one may die annually, the mean age at death may be twenty-nine, the mean age of the living may be twenty-six, and the mean expectation of life may be thirty-seven, in the same population at the same time." (*Essays on some Fallacies of Statistics*, 1875, p. 211.) Sir E. Chadwick found that in fairly healthy districts the mean age of the living was to the mean age at death as about 3 to 4, while in insanitary districts with shifting and increasing populations the line of vitality was higher than that of mortality. But this is due to the fact that under insanitary conditions a high mortality spends itself chiefly among young children, and, in addition, there are always crowds of young and healthy persons ready to immigrate from country to town, thus lowering the mean age of the town populations, among whom insanitary conditions are especially rife. On the whole, therefore, the mean age of the living as a test of the duration of life is as untrustworthy as is the mean age of the dying.

The **Probable Duration of Life** (also called equation of life, or *vie probable*) is a term used to signify the age at which any number of children born into the world will be reduced to one-half, so that there are equal chances of their dying before and after that age. The name is unfortunate, as every possible duration of life has a probability which may be determined, and is therefore mathematically a "probable lifetime." Using the term in its limited sense, the English experience in 1838–54 gave a probable lifetime for males at birth of 44–45 years, while according to the experience of 1881–90 it was 51–52 years.

De Moivre's Hypothesis. This assumed that the decrements of population are in arithmetical progression, and that of every eighty-six persons born, one would die uniformly every year until all were extinct. Such an assumption was convenient in the calculation of annuity tables, before accurate life-tables were constructed. According to this hypothesis there is no such function as the probable duration of life, the probability of death in any year being as great as in any other. It confessedly errs greatly at the beginning and end of life, and is only a very rough approximation to the truth for the middle period of life.

The Mean Duration of Life, or *vie moyenne*, is a term which has unfortunately been employed with different significations.

The following table of the diverse mathematical expressions to which the name *vie moyenne* has been given is taken from Bertillon (*op. cit.* p. 75):—

Vie Moyenne, France, 1840–49.

	Years.
True *vie moyenne* (expectation of life)	40·05
Mean age of persons enumerated at census	30·92
„ deceased persons	35·66
Number of population out of which one birth occurs	38·00
„ „ „ „ death „	43·50
Mean between the two preceding values (Price's formula)	40·75
Vie probable, according to life-table	43·30
„ „ „ death-returns	33·50

In a stationary population, undisturbed by migration or other causes, expectation of life and the mean age at death are, as we have already seen, identical. In populations as ordinarily constituted the term "mean duration of life" should not be employed except as synonymous with expectation of life or mean after-lifetime; and having regard to its loose application it would be preferable to drop it altogether. By some actuaries the term is employed somewhat differently from the term expectation of life. Thus at birth both expectation and duration of life according to the English experience of 1881–90 was 43·66 years for males; while at the age of 30 years the expectation of life for males was 32·52 years, and the true mean duration of life for men aged 30 years was $30 + 32{\cdot}52 = 62{\cdot}52$ years. In other words at all ages after birth the mean duration of life is the present age added to the expectation of life. This distinctive use of the term "duration of life" is not adopted by Milne and Farr, and is only mentioned here to avoid possible confusion in reading the literature of life-tables.

The Expectation of Life (synonyms: mean after-lifetime, mean duration of life, *vie moyenne*) is found as already described (p. 261) from a life-table. A life-table shows how many of a given number, started with at a given age, live through each subsequent year of life, and what is the sum of the number of years they live. The expectation of life is obtained by dividing the sum of these years by the number living at the year of age from which the expectation of life is desired.

The expectation of life at different ages, and according to different life-tables, is shown in the following table:—

Expectation of Life (Mean After-lifetime) according to various Life-Tables at successive Ages.

Years of Age.	De Moivre's Hypothesis.	Northampton Table.	Carlisle Table.	English Life-Table, No. 1.	English Life-Table, No. 2.	English Life-Table, No. 3, 1838–54.		English Life-Table (Ogle), 1871–80.		English Life-Table (Tatham) 1881–90.	
	Persons.					Males.	Females.	Males.	Females.	Males.	Females.
0 . .	43	25·2	38·7	41·1	—	39·91	41·85	41·35	44·62	43·66	47·18
5 . .	40·5	40·8	51·3	50·0	—	49·71	50·33	50·87	53·08	52·75	54·92
10 . .	38	39·8	48·8	47·2	47·5	47·05	47·67	47·60	49·76	49·00	51·10
15 . .	35·5	36·5	45·0	43·6	43·4	43·18	43·90	43·41	45·63	44·47	46·55
20 . .	33	33·4	41·5	40·3	40·0	39 48	40·29	39·40	41·66	40·27	42·42
25 . .	30·5	30·9	37·9	37·0	36·6	36·12	37·04	35 68	37·98	36·28	38·50
30 . .	28	28·3	34·3	33·6	33·1	32·76	33·81	32·10	34·41	32·52	34·76
35 . .	25·5	25·7	31·0	30·4	29·8	29·40	30·59	28·64	30·90	28·91	31·16
40 . .	23	23·1	27·6	27·1	26·5	26·06	27·34	25·30	27·46	25·42	27·60
45 . .	20·5	20·5	24·5	23·8	23·1	22·76	24·06	22·07	24·06	22·06	24·05
50 . .	13	18·0	21·1	20·6	19·9	19·54	20·75	18·93	20·68	18·82	20·56
55 . .	15·5	15 6	17·6	17·1	16·7	16·45	17·43	15·95	17·33	15·74	17·23
60 . .	13	13·2	14·3	14·0	13·6	13·53	14·34	13·14	14·24	12·88	14·10
65 . .	10·5	10·9	11·8	11·1	10·9	10·82	11·51	10·55	11·42	10·31	11·26
70 . .	8	8·6	9·2	8·7	8·6	8·45	9·02	8·27	8·95	8·04	8·77
75 . .	5·5	6·5	7·0	6·7	6·6	6·49	6·93	6·34	6·87	6·10	6·68
80 . .	3	4·8	5 5	5·1	5·0	4·93	5·26	4·79	5·20	4·52	5·00
85 . .	0·5	3·4	4·1	3·7	3·7	3·73	3·98	3·56	3·88	3·29	3·71
90 . .	—	2·4	3·3	2·7	—	2·84	3·01	2 66	2·90	2·37	2·75
95 . .	—	0·8	3·5	2·1	—	2·17	2·29	2·01	2·17	1·72	2·05
100 . .	—	—	2·3	—	—	1·68	1·76	1·61	1·62	1·24	1·54

For the expectation of life in selected healthy districts of England see p. 308.

A number of local life-tables have been constructed, based on the experience of the decennium 1881–90, and a comparative view of English experience in different localities can thus be obtained:—

EXPECTATION OF LIFE.

Years of Age	London* (Murphy)	Brighton † (Newsholme)	Portsmouth (Mumby)	Manchester ‡ (Tatham)		Oldham † (Tattersall)	Haydock, Lanc. § (Hayward)	Glasgow (Chambers)
				Township	City			
	MALES.							
0	40·66	43·59	43·68	28·78	34·71	36·88	46·17	35·18
5	50·77	52·87	52·86	40·53	45·59	46·90	53·81	46·97
10	47·22	49·12	48·64	37 47	42·75	43·81	50·12	44·32
15	42·88	44·67	44·27	33·56	38·78	39·59	45·91	40·51
20	38·70	40·55	40·06	29·61	34·62	35·73	41·45	36·90
25	34·70	36·51	36·10	26·00	30·69	31·96	37·00	33·29
35	27·39	29·02	28·75	20·01	23·76	24·82	28·81	26·06
45	21·00	22·36	22·06	14·93	17·80	18·44	21·98	19·54
55	15·31	16·48	15·98	10·96	12·49	12·83	15·24	13·39
65	10·59	10·96	10·34	7·48	8·15	8·05	9	9·38
75	7·20	6·64	5·76	4·74	5·11	4·93		5·96
	FEMALES.							
0	44·91	49 25	46·02	32·67	38·44	40·75	46·95	37·70
5	54·42	57·36	53·45	43·66	48·06	49·97	54·41	48·27
10	50·95	53·60	50·39	40·94	45·43	46·44	50·37	45·44
15	46·65	49·26	46·37	37·05	41·50	42 33	46·20	41·59
20	42·45	44·95	42·23	33·08	37·33	38·47	42·11	38·00
25	38·34	40·68	38·30	29·41	33·38	34·65	38·36	34·60
35	30·69	32·69	30·97	22·90	26·30	27·63	30·98	28·06
45	23·80	25·30	24·14	17·20	19·79	20·57	23·07	21·61
55	17·34	18·48	17·46	12·25	13·91	14·10	16·30	15·60
65	11·78	12·19	11·08	8·54	9·11	8·87	9·91	10·69
75	7·79	6·97	6·12	6·03	5·76	5·16	5·35	6 97

* The London Life-Table was calculated by Farr's "short method."

† The Brighton and the Oldham Life-Tables were constructed by the graphic method.

‡ Dr. Tatham has constructed three life-tables for Manchester: for Manchester city, including all the townships of which it consists; for Manchester township, the central and most crowded part of the city; and for Manchester outlying townships.

§ The Haydock Life-Table was calculated by a modified short method.

It should be observed that the expectation of life is the *average* number of years which persons of a given age, taken one with another, live, assuming that they die according to a given table of the probabilities of life. The term "expectation of life" does not imply that an individual may reasonably expect to live a given number of years. The excess of those who die late is distributed among those who die early, "those who live longer enjoying as much more in proportion to their number, as those who fall short enjoy less of life." Thus the expectation of life has no relation whatever to the most probable lifetime of any given individual.

Many attempts have been made in the absence of a life-table to ascertain the expectation, but none of them give trustworthy results.

The **formula of Willich** gives approximate results for ages between 25 and 75.

It is as follows:—

If x = expectation of life, and a = present age, then

$$x = \tfrac{2}{3}(80 - a).$$

Thus at the age of 45 years the expectation of life according to this formula $= \tfrac{2}{3}(80 - 45) = 23\cdot3$ years. According to the English Life-Table (p. 299) it varies from 22 for men to 24 for women.

Dr. *Bristowe's formula* has been already given, and its limitations explained (p. 295). Dr. *Farr* gave the following *formula*, for obtaining an approximation to the expectation of life at birth when the birth-rate and death-rate are known.

If b = birth-rate and d = death-rate per unit of population, then the expectation of life $= \left(\frac{2}{3} \times \frac{1}{d}\right) + \left(\frac{1}{3} \times \frac{1}{b}\right)$.

Thus in the decennium 1881–90, the birth-rate in England and Wales was ·03234, and the death-rate ·01908 per unit. The expectation of life $= \left(\frac{2}{3} \times \frac{1}{\cdot01908}\right) + \left(\frac{1}{3} \times \frac{1}{\cdot03234}\right) = 45\cdot6$ years, while the expectation of life shown by the English Life-Table for males and females combined was 45·4 years.

These formulæ might be used without misleading to any considerable extent when applied to a given community for successive years. They would be misleading if employed for comparing communities having widely different birth-rates.

Probabilities of Life. It is sometimes desirable to ascertain not only the probable duration of life, but also the probability of dying within a given period.

In mathematical language, the words *chance* and *probability* are used as synonymous; but in common language the first word is used when the expectation that an event will happen is small, and the second when it is large.

If the number of possible events $= a + b$, of which a are favourable and b unfavourable, and if $p =$ the probability of a favourable event happening, and $q =$ the probability of an unfavourable event happening, then, on the supposition that one of these events happens, $p = \frac{a}{a+b}$; $q = \frac{b}{a+b}$; where $p + q = 1$, or certainty.

Thus, if we wish to find the probability of a man aged 30 living till he is 50, and also the probability that he will die before that age, we consult the life-table for males. From this we find that the number living (out of a million males born) at 30 is 669,279; at 50 is 517, 639. Therefore the probability of a man aged 30 living to 50 $= \frac{517639}{669279}$.

And as $669{,}279 - 517{,}639 = 151{,}640 =$ the number dying during the period; therefore $\frac{151640}{669279}$, or $1 - \frac{517639}{669279} =$ probability of dying between 30 and 50.

If there be several independent events, the probabilities of the happening of which are respectively p_1, p_2, p_3, etc., then the probability that all the events will happen is $p_1 \times p_2 \times p_3 \times$ etc.; that all will fail $(1 - p_1)$ $(1 - p_2)$ $(1 - p_3)$ etc.; that at least one event will happen, $1 - (1 - p_1)$ $(1 - p_2)$ $(1 - p_3)$ etc.; and that exactly one will happen and all the rest fail, $p_1(1 - p_2)$ $(1 - p_3)$ etc. $+ p_2(1 - p_1)$ $(1 - p_3)$ etc. $+ p_3(1 - p_1)$ $(1 - p_2)$ etc. + etc.

Thus, if $p = \frac{a}{a+b}$ and $p_1 = \frac{c}{c+d}$, then the probability that both will happen is $\frac{a}{a+b} \times \frac{c}{c+d}$, and the probability that neither will happen is this amount subtracted from unity.

Thus, the probability that a married couple—the husband's age being 40, and that of the wife 35—will both live 15 years, is obtained as follows:—

By the English Life-table, 1881-90, out of 1,000,000 of each sex at birth, there are—

Of males at 40 years old, 604,923; at 55 years old, 462,981.
Of females „ 35 „ 638,912; „ 50 „ 516,375.

The probability of both these persons surviving 15 years from their present age $=\frac{462981}{604923}\times\frac{516375}{638912}$, which product gives the required result.

CHAPTER XXV.

CHANGES IN THE ENGLISH EXPECTATION OF LIFE.

IT is plain from the facts detailed in the next chapter, that in 1871–80 the death-rate among adults was somewhat higher than it had previously been, while that at earlier ages was considerably lower, but that in 1881–90 there was no further increase in the adult death-rate, although persons over the age of 45 only shared to a slight extent in the marked decline in the death-rate at earlier ages, which had been showing itself.

The following table brings the comparison up to recent years:—

Annual Death-rates per 1000 Living at Twelve Age-periods in Groups of Years. England and Wales.

Period.	All Ages.	0-	5-	10-	15-	20-	25-	35-	45-	55-	65-	75-	85 and upwards.
		MALES.											
1886–90 .	20·0	61·9	4·9	2·8	4·1	5·5	7·4	12·0	19·4	35·2	72·1	147·9	313·8
1891–95 .	19·8	62·1	4·5	2·5	4·0	5·3	7·2	12·2	19·8	36·3	71·9	149·9	290·6
		FEMALES.											
1886–90 .	17·8	52·0	4·9	2·9	4·1	5·2	6·9	10·3	15·0	28·8	61·7	132·3	276·2
1891–95 .	17·7	52·0	4·5	2·7	4·0	4·9	6·7	10·3	15·3	29·8	62·8	136·1	263·8

The death-rates shown in the above table may be described as practically stationary. It is highly probable that influenza and its complications are responsible for the fact that 1891–95 does not compare more favourably than it does with 1886-90.

A cursory perusal of the preceding facts may suggest the conclusion that, as there has been but little decline in the death-rate affecting those who are living in the most useful working period of life, the gain to the community is correspondingly small.

But such a view of the matter loses sight of the important fact that a *larger proportion of those born survive to the non-dependent or useful ages.* This is brought out by the life-table; and the only non-fallacious method of studying this question is by means of a life-table founded on the number living and the number dying at each age.

The facts are so well summarized by Dr. Tatham in his account of the English Life-Table for 1881–90, that his account is reproduced here verbatim.

"*Males.* By the table of 1838–54, a million males born are reduced to half a million during the 45th year of age; by the table of 1871–80, this amount of reduction is not reached until the 48th year, and by the new table it is further postponed until the 52nd year. At the end of the first year of age the number of survivors by the new table occupies an intermediate position between the numbers by the two previous tables; at every other age until 79 the new table shows a larger number of survivors than is shown by either of the older tables; from age 84 onwards, the survivors are fewer by the new table than by either of the others. This change is probably due, in part at least, to more accurate statement of age in recent than in earlier years.

"The average lifetime of males, or the expectation of life at birth, which had been 39·91 years by the first of the three life-tables, and 41·35 years by the second, is further increased by the new life-table to 43·66 years; that is to say, a male exposed throughout life to the rate of mortality obtaining in England and Wales in 1881–90, would on an average live 2·31 years longer than he would have lived had he been subject to the rates prevalent in 1871–80, and 3·75 years longer than he would have lived had he been subject to the rates prevalent in 1838–54. In the last decennial report it was shown that the expectations of life among males by the life-table therein published were higher than those by the earlier table for ages below 19, equal thereto at age 19, and lower at all subsequent ages. The new life-table shows improved expectations of life, compared with those in the earlier tables, up to 26 years of age; from age 27 until age 44 the expectations are lower than those in the first table, but higher than those in the 1871–80 table; for ages 45 and upwards the expectations of life are lower by the new table than by either of the others.

"According to the first life-table, the 495,770 survivors at age 45, out of a million males born, will live about 11,284,000 years of life, or an average of 22·76 years each; according to the second life-table the 522,374 survivors at the same age will live about 11,529,000 years of life, or an average of 22·07 years each; and according to the new life-table the 564,437 survivors at the same age will live 12,451,000 years of life, or an average of 22·06 years each. The successive additions to the working time of life may be shown in a striking form by considering the years lived between the ages 20 and 60. A short calculation shows that the average numbers of years lived between these limits of age by each male born are 20·92, 22·00, and 23·56, respectively, according to the three life-tables.

"*Females.* By the two earlier tables a million female children born were reduced to half a million in the 47th and 53rd years of age respectively; by the new table this amount of reduction is not reached until the 57th year. As in the case of males, the number of infants surviving at the end of the first year of life by the new table is intermediate between the numbers similarly surviving by the earlier tables. At all other ages until 85 inclusive the numbers surviving are greater by the new table than by either of the others; but as is also the case among males, the numbers of survivors at extreme ages diminish more rapidly by the new table than by either of the older ones. The expectation of life at birth, which had been 41·85 years and 44·62 years respectively in the earlier tables, is further increased by the new table to 47·18 years. The expectations at the several ages up to 44 years are greater by the new table than by either of the others. At age 44 and again at age 45 the expectations of life by the three tables are practically equal, being 24·72, 24·74, and 24·75 respectively at age 44, and 24·06, 24·06, and 24·05 at age 45. At all ages beyond 45, the expectations of life are less by the new table than by either of the previous tables. The average numbers of years lived between the ages 20 and 60 by each female born are 21·65, 23·48, and 25·12 by the three life-tables respectively."

It is clear from the above facts, even when 1871–80 is compared with 1838–54, that, as pointed out by Dr. Ogle, the survivors at the end of the 45th year are so much more numerous than they were under the rate of mortality prevailing in 1838–54, that "they can support the higher mortality of after years for a considerable period and yet retain their numerical superiority." Thus the aggregate life of the community at the most useful years of life is greater than under former conditions. This is true to a much greater extent for 1881–90, when the death-rate in adult life was lower than in the preceding decade, and the number of survivors from earlier ages was greater than in either of the two preceding national life-tables.

The student's attention may be called in passing to a comparison of the tables on pp. 315 and 307 (below). The first table shows that the death-rate among males was lower, with a solitary and slight exception, at every age period in 1881–90 than in 1871–80. The second table shows the apparently inconsistent fact that, notwithstanding the lower death-rate, the male expectation of life was less favourable at ages over 45 in 1881–90 than in 1871–80. The key to the anomaly is found in the fact that the expectation of life at any given age takes into account the total number of survivors from all lower ages, and these were more numerous out of a given number at birth, according to the experience of 1881–90, than according to that of 1871–80.

For the purpose of easy comparison the facts tabulated on p. 299 may be shown by differences as follows:—

INCREASE OR DECREASE OF EXPECTATION OF LIFE AT FIVE-YEARLY INTERVALS OF AGE, THE ENGLISH LIFE-TABLE FOR 1871-80 BEING COMPARED WITH THAT FOR 1838-54, AND THE ENGLISH LIFE-TABLE FOR 1881-90 WITH THAT FOR 1871-80.

Age.	MALES, Increase or Decrease of		FEMALES, Increase or Decrease of	
	1871–80 compared with 1838–54.	1881–90 compared with 1871–80.	1871–80 compared with 1838–54.	1881–90 compared with 1871–80.
0 . . .	+1·44	+2·31	+2·77	+2·56
5 . . .	+1·16	+1·88	+2·75	+1·84
10 . . .	+0·55	+1·40	+2·09	+1·34
15 . . .	+0·23	+1·06	+1·73	+0·92
20 . . .	−0·08	+0·87	+1·37	+0·76
25 . . .	−0·44	+0·60	+0·94	+0·52
30 . . .	−0·66	+0·42	+0·60	+0·35
35 . . .	−0·76	+0·27	+0·31	+0·26
40 . . .	−0·76	+0·12	+0·12	+0·14
45 . . .	−0·69	−0·01	0·00	−0·01
50 . . .	−0·61	−0·11	−0·07	−0·12
55 . . .	−0·50	−0·21	−0·10	−0·10
60 . . .	−0·39	−0·26	−0·10	−0·14
65 . . .	−0·27	−0·24	−0·07	−0·16
70 . . .	−0·18	−0·23	−0·07	−0·18
75 . . .	−0·15	−0·24	−0·06	−0·19
80 . . .	−0·14	−0·27	−0·06	−0·20
85 . . .	−0·17	−0·27	−0·10	−0·17
90 . . .	−0·18	−0·29	−0·11	−0·15
95 . . .	−0·16	−0·29	−0·12	−0·12

The real facts of the case are brought out clearly when the figures contained in the fourth column of the life-table on p. 275, or the corresponding figures in other life-tables are examined. The number in this column opposite any age represents the total number living at all higher ages, or the total number of years lived by them. Thus in the Brighton Life-Table 51,195 males born live 2,206,174 complete years, 38,283 living at the fifth year of age subsequently live 2,005,945 complete years.

Hence 2,206,174 - 2,005,945 = 200,229, the number of complete years lived between birth and 5 years of age, and the average for each is obtained by dividing by the number living at the earlier age.

In the following table (*Registrar-General's Decennial Supplement*, part ii. p. cxiv) Dr. Tatham shows how the mean lifetime or expectation of life is distributed in six life-tables over several life-periods.

Life Period.	Age-limits of Period.	Length of Period in Years.	England and Wales.			Manchester Township.	Selected Healthy Districts.	
			1838–54.	1871–80.	1881–90.	1881–90.	1849–53.	1881–90.
			MALES.					
Infancy .	0–5	5	3·94	4·01	4·02	3·51	4·29	4·30
School age .	5–15	10	6·92	7·11	7·35	5·95	7·88	8·13
Adolescence .	15–25	10	6·51	6·79	7·12	5·55	7·50	7·89
Maturity .	25–35	10	5·95	6·29	6·69	4·90	6·95	7·49
	35–45	10	5·31	5·62	6·04	3·89	6·37	6·95
	45–55	10	4·54	4·76	5·16	2·71	5·72	6·25
	55–65	10	3·55	3·63	3·96	1·51	4·82	5·22
Decline .	65 and upwards	—	3·19	3·14	3·32	0·76	5·03	5·25
Total .	All ages	—	39·91	41·35	43·66	28·78	48·56	51·48
			FEMALES.					
Infancy .	0 5	5	4·07	4·14	4·17	3·71	4·39	4·43
School age .	5–15	10	7·19	7·40	7·68	6·32	8·07	8·41
Adolescence .	15–25	10	6·73	7·07	7·44	5·92	7·61	8·12
Maturity .	25–35	10	6·12	6·58	6·99	5·35	7·00	7·69
	35–45	10	5·46	5·95	6·38	4·50	6·37	7·15
	45–55	10	4·73	5·20	5·63	3·42	5·71	6·53
	55–65	10	3·82	4·21	4·55	2·16	4·89	5·60
Decline .	65 and upwards	—	3·73	4·07	4·34	1·29	5·41	6·11
Total .	All ages	—	41·85	44·62	47·18	32·67	49·45	54·04

Comparing the three national life-tables with each other, it will be seen that the expectation of life has improved at all age-periods, and not only at the earlier age-periods, in which the chief reduction of death-rate has occurred.

Dr. Tatham has summarized the teaching of the above table in the following:—.

		England and Wales.			Manchester Township, 1881–90.	Selected Healthy Districts.	
		1838–54.	1871–80.	1881–90.		1849–53.	1881–90.
Average lifetime between 15 and 65 years of age .	Males .	25·86	27·09	28·97	18·56	31·36	33·80
	Females	26·86	29 01	30 99	21·35	31·58	35·09
Percentage of the entire age-period of 50 years, 15–65	Males .	52	54	58	37	63	68
	Females	54	58	62	43	63	70

Taking the age 15 to 65 to represent the effective or working period of life, it will be seen that men on an average have a longer lifetime in this period of life, according to the experience of 1881–90, than in either of the earlier life-tables.

It is somewhat remarkable that in all the above six life-tables the proportion of the total lifetime which is lived between the ages 25 and 55 differs very little from 40 per cent. Dr. Tatham adds: "It follows that in each of these six life-tables about 60 per cent. of the average lifetime is lived partly before 25 years of age, and partly after 55 years of age; and the distribution of this 60 per cent. between the earlier and the later ages would therefore enable us to distinguish between life-tables for healthy and for unhealthy districts or periods without referring to the respective mean lifetimes."

Healthy Districts Experience. The basis of experience on which the new Healthy Districts Life-Table has been calculated is stated on p. 289, and the facts as regards infantile mortality in this life-table are given on p. 123. The tables on pp. 308 and 309 will enable a more complete comparison for other age-periods to be made between the two Healthy Districts Life-Tables and Life-Tables for Manchester Township, and for the whole of England and Wales at different periods.

Local Experience. A similar comparison between the experience of different great towns in the decennium 1881–90 can be made by means of the data which are summarized on p. 300.

Life Capital. In a valuable *Report on the Health of Greater Manchester*, 1891–93, Dr. Tatham has shown how the life-table may be applied to ascertain what he happily describes as the life-capital of a community. As already seen, the number of persons living at any age in a life-table represents a certain number of years of life, which number is measured by their expectations of life as shown in the life-table.

The following formula gives the means for determining the mean expectation of life or after-lifetime of persons in groups of ages, like those in which death-rates are usually stated.

The future lifetime of l_x persons is Q_x, and the mean expectation of life of each of these persons is $\frac{Q_x}{l_x}$. The future lifetime of P_x persons living at all ages between x and $x+1$ is $Q_x - \frac{P_x}{2}$, the mean expectation of life of each being $\frac{Q_x}{P_x} - \frac{1}{2}$. The future lifetime of $P_x + P_{x+1} + \ldots\ldots + P_{x+n-1}$ persons living at all ages between x and $x+n$ is

$$\{Q_x + Q_{x+1} + \ldots\ldots + Q_{x+n-1}\} - \tfrac{1}{2}\{P_x + P_{x+1} + \ldots\ldots + P_{x+n-1}\}$$

and their mean expectation of life is

$$\frac{Q_x + Q_{x+1} \ldots\ldots\ldots\ldots + Q_{x+n-1}}{P_x + P_{x+1} \ldots\ldots\ldots\ldots + P_{x+n-1}} - \tfrac{1}{2}.$$

In the above formula it will be noted, to take an example, that not only does

$$P_5 = \frac{l_5 + l_6}{2}, \text{ but that also}$$

$$P_5 = l_6 + \frac{d_5}{2}.$$

Thus in the English Life-Table

$P_5 = 382{,}921 = \frac{384432 + 381410}{2}$. Also $P_5 = 381410 + \frac{3022}{2} = 382{,}921$.

The method can be shown by the following illustration from the Brighton Life-Table. In addition to the columns printed on p. 275, two further columns are required, viz., P_x, the mean population for each year of life, and Q_x the population or years of life lived in and above each year. For all years of life except the first P_x is taken as the arithmetical mean of l_x and l_{x+1}, as in the English Life-Table for 1881–90. For the first year of life a special method is required.

(*a*) In the English Life-Table, 1881–90, it is assumed that each male dying during the first year of life enjoys ·37539 year of life, and each female ·38280 year.

This figure is obtained as follows. According to the English Life-Table for males

$$\begin{aligned} \text{Mean population } 0\text{-}1 = P_o &= 457817 \\ \text{Population at age } \ 1 = l_1 &= 427184 \\ \text{Difference} &= \overline{30633} \end{aligned}$$

This is the number of years lived by the $d_o = 81996$ males dying during the first year of life.

∴ the average lifetime of the males dying in the first year of life $= \frac{30633}{81996} = \cdot 37539$ year.

If we assume that the same proportionate amount of life holds good for those dying in Brighton in the first year of their life, then

$l_0 - l_1 = 51{,}195 - 43{,}315 = 7880$

= the number of males dying in the first year of life.

$7880 \times \cdot 37539 = 2958$ = number of years lived by those dying in the first year of life.

But those surviving to the end of the first year live 43,315 years.

∴ $43{,}315 + 2958 = 46{,}263$ = total number of years lived in the first year of life, *i.e.*, the mean population for that year.

In subsequent years the arithmetical mean is taken, *i.e.*,

$$\frac{l_x + l_{x+1}}{2} = P_x.$$

For the sake of convenience the above method has been adopted here.

(*b*) It would have been practicable to deduce the mean number living 0–1 from the recorded proportion of deaths occurring at each month of the first year of life. Thus 51·1 per cent. of the deaths under one occurred under 3 months of age, 22·2 per cent. at ages 3–6 months, 14·5 per cent. at ages 6–9 months, and 12·2 per cent. at ages 9–12 months.

To obtain accurate results it would be desirable to subdivide still further. Thus out of 114 male deaths aged 0–3 months, 76 occurred under 1 month, and 44 under 1 week of age.

Applying the preceding formula to the Brighton Life-Table, the following result is obtained:—

Age-groups.	Sum of Mean Populations for each Age-group.	Sum of Populations at each Age-group and upwards.	Mean Expectation of life in groups of Ages.
0– 4 . . .	205692	10876144·5	52·88
5– 9 . . .	188760	9748089·5	51·64
10–14 . . .	185843	9091081·5	48·92
15–19 . . .	182875	7887198·5	43·13
20-24 . . .	178819	6980593·5	39·04
25-35 . . .	340826	11336356·0	33·26
35–44 . . .	280067	8062297·0	28·79
45–54 . . .	259762	5187970·0	19·97
55–64 . . .	219161	2842473·0	12·97
65–74 . . .	124983	1183580·0	9·47
75-84 . . .	50220	282970·0	5·60
85 and upwards .	6160	22492·0	3·65

If we compare the actual number of deaths in Brighton in 1897 with those which would have occurred had its population suffered from the mean death-rate of the ten years 1881–90, we obtain the following result:—

Age-period.	Mean Male Population in 1897.	Mean Death-rate in 1881-90.	Calculated number of Deaths in 1897 according to the rates of 1881-90.	Actual number of Deaths in 1897.	Gain of Lives in 1897.	Gain of Life Capital in 1897.
0– . .	6218	64·01	398	324	+74	3913·12
5- . .	6340	4·83	31	14	+17	877·88
10– . .	5963	2·30	14	10	+ 4	195·68
15- . .	5244	4·13	22	20	+ 2	86·26
20- . .	4393	5·05	22	19	+ 3	117·12
25– . .	8058	7·72	62	45	+17	565·42
35– . .	6472	12·94	84	70	+14	403·06
45– . .	4750	21·17	101	88	+13	259·61
55– . .	3170	32 76	104	87	+17	220·49
65– . .	1947	64·36	125	114	+11	104·17
75– . .	727	132·29	96	95	+ 1	5·60
85 & upwards	121	293·8	36	22	+14	51·10
	53403		1095	908	187	6799·51

The last column is obtained by multiplying each life gained by the superiority of 1897 over the mean of 1881–90 by the mean expectation of life for the corresponding age-period. Thus—

$$52{\cdot}88 \times 74 = 3913{\cdot}12.$$

The greater amount of saving at the earlier ages of life represents a greater gain to the community than could have been foreseen, apart from the application of the preceding method.

The same method may be applied to the entire population of a community. Thus by multiplying the population at each age-group in the preceding table by the mean expectation of life for the same age-group, we obtain the total life-capital of the community, and $\frac{\text{life-capital}}{\text{population}}$ = average life-capital or future lifetime of each member of the population.

Furthermore, as mean population has been shown to be equal to years of life expended in a year, $\frac{\text{population} \times 100}{\text{life-capital}}$ = proportion per cent. of life-capital expended in a year.

CHAPTER XXVI.

THE DECLINE IN THE ENGLISH DEATH-RATE AND ITS CAUSES.

WE have in chapter xv. p. 149 *et seq.* dwelt on the fall in the general death-rate, following on the passing of the Public Health Act of 1875. In order to determine the extent and value of this decline, it is necessary to study the deaths at varying ages in proportion to the number living at these ages, and the influence of the lower death-rate on the expectations of life at different ages. The necessary data for the first part of this study are contained in the following table:—

MEAN ANNUAL DEATH-RATE PER 1000 IN ENGLAND AND WALES AT ELEVEN GROUPS OF AGES, IN GROUPS OF YEARS.

	PERSONS.				
Ages.	1841-50.	1851-60.	1861-70.	1871-80.	1881-90.
All Ages . . .	22·28	22·17	22·42	21·27	19·08
0-	66·03	67·60	68·30	63·12	56·82
5-	9·03	8·46	7·95	6·43	5·29
10-	5·27	4·97	4·47	3·70	3·02
15-	7·46	7·04	6·39	5·33	4·35
20-	9·28	8·67	8·19	7·04	5·61
25-	10·25	9·76	9·79	8·93	7·53
35-	12·85	12·31	12·72	12·62	11·42
45-	17·03	16·54	17·30	17·72	17·06
55-	29·86	28·86	30·28	31·49	31·33
65-	63·59	61·74	62·45	64·85	64·65
75 and upwards .	162·81	159·78	158·79	161·59	153·67

The teaching of the preceding table is made plainer by stating the reductions in death-rate as percentages, as in the following table in which 1881–90 is compared with 1871–80 for the two sexes separately :—

MEAN ANNUAL DEATH-RATE PER 1000 IN ENGLAND AND WALES AT ELEVEN GROUPS OF AGES, IN GROUPS OF YEARS, WITH PERCENTAGE DIFFERENCES.

	MALES.			FEMALES.		
Ages.	1871–80.	1881–90.	Increase or Decrease per cent. in 1881–90 compared with preceding Decennium.	1871–80.	1881–90.	Increase or Decrease per cent. in 1881–90 compared with preceding Decennium.
All Ages . .	22·61	20·22	– 10·6	20·00	18·01	– 10·0
0– . . .	68·14	61·69	– 9·5	58·10	51·99	– 10·5
5– . . .	6·67	5·34	– 19·9	6·20	5·25	– 15·3
10– . . .	3·69	2·94	– 20·3	3·70	3·09	– 16·5
15– . . .	5·23	4·30	– 17·8	5·43	4·40	– 19·0
20– . . .	7·32	5·71	– 22·0	6·78	5·51	– 18·7
25– . . .	9·30	7·73	– 16·9	8·58	7·34	– 14·5
35– . . .	13·74	12·35	– 10·1	11·58	10·55	– 8·9
45– . . .	20·05	19·28	– 3·8	15·59	15·04	– 3·5
55– . . .	34·76	34·66	– 0·3	28·54	28·40	– 0·5
65– . . .	69·57	70·17	+ 0·9	60·82	60·08	– 1·2
75 and upwards	169·08	162·18	– 4·1	155·83	147·32	– 5·5

It will be seen that in both sexes the decline in the general death-rate, comparing the eighth with the ninth decade of this century, amounted to about 10 per cent. There was a decreased mortality among females at every age-period, and among males a decrease at all but the age-period 65–75. When comparing the eighth decade with the seventh Dr. Ogle had shown that, "speaking generally, the death-rates fell for the earlier age-periods, while they rose for the later periods of life" . . . . "the male death-rate being higher than in the preceding decennium at each period after 35 years of age, while the female death-rate did not show an increase until after 45 years of age." In commenting on the facts brought out in Dr. Ogle's decennial supplement for 1871–80, the writer several years ago made the following remarks, which may appropriately be quoted here (Brighton Life-Table, 1893, p. 25 *et seq.*) :—

"(*a*) A favourite explanation of the increased death-rate and diminished expectation of life in adult years is that, owing to the saving of life in the earlier years of life—a saving which has been especially in zymotic diseases and phthisis and other tubercular diseases—there has been a larger number of weakly survivors, who would under the former *régime* have been carried off by these diseases. In other words, the operation of the law of the survival of the fittest has been impeded, with results unfavourable to the health and vigour of adult life. This argument assumes that weakly children are more prone to attack by infectious diseases than robust children, an assumption which experience does not confirm. These diseases appear to attack the majority of children, weakly or robust, who are exposed to their infection. It might be reasonably expected, therefore, that with a decrease in the total deaths from infectious diseases, there would have been at least a corresponding decrease in the number of those who are left maimed by an attack of one of these diseases to survive to adult life. We personally think that the weeding out of weakly lives, caused by the greater mortality among weakly children suffering from an infectious disease, is almost entirely counterbalanced by the greater number of children made weakly in former times by non-fatal attacks of an infectious disease.

"The case for deterioration of the race by survival of patients who would formerly have died in early life from phthisis and other tubercular diseases, appears to be a stronger one. It is probable that a larger proportion of phthisical patients are cured than formerly. It is probable also that many more children with a strong tendency to phthisis, or even suffering from its early symptoms, are prevented by the improved medical treatment and the improved social conditions of recent years, from developing the disease. These now may survive to adult life and become the parents of children with a strong tubercular tendency.

"Such a fact need not, however, cause any serious apprehension for two reasons. In the first place, hereditary tendencies to phthisis only act under favourable predisposing conditions, such as damp and overcrowded houses, sedentary occupation in a cramped position, etc.; and in presence of the active exciting agent, the specific *bacillus tuberculosis* introduced *ab extra* by inhalation or by means of food.

"(*b*) Assuming that more phthisical patients survive than formerly, is it not equally true that fewer persons *become* phthisical than formerly? With a diminution of the active cases of phthisis, the number of centres for phthisical sputum, which, as dust, is the chief cause of subsequent infection, must have diminished to a corresponding extent. Of the fact that the predisposing causes of phthisis—damp and overcrowded houses, ill-ventilated workshops, etc.—are steadily diminishing, there is evidence on every hand. It is, therefore, reasonable to suppose that much at least of the deteriorating effect of survival of tubercular persons is counterbalanced by the large number of persons who are *prevented by improved sanitary and social conditions from becoming tubercular*.

"It is premature at present to attempt by statistical means to determine how far the counteracting influences which are at work, balance each other, or failing a balance on which side is the preponderating effect.

"(*c*) The increased stress of modern life is supposed by many to explain the increased death-rate among adults. It is doubtful if such increased strain exists in the community as a whole. Each adult as he becomes year by year more deeply involved in the battle of life, comes to the conclusion that the general strain of life in the community is increasing, forgetting that the same causes operated as life advanced in previous generations. There is reason for thinking with Dr. Pye-Smith that much of the evil ascribed to 'over-pressure' is really due to over-feeding and drinking.

"Assuming, however, that over-pressure exists in certain stations of life, *e.g.*, among city merchants, medical men, etc., it cannot be said to exist generally among professional men. Clergymen, lawyers, and civil-servants are as classes long-lived.

"Even assuming that over-pressure exists throughout the whole of the professional and mercantile classes, these do not form the mass of the community. *The majority of the population of England and Wales belong to the wage-earning classes*, and the conditions of these classes will therefore necessarily have the greatest influence on the total result. What are the facts as regards these classes? They may be gathered from an important address by Mr., now Sir R. Giffen.* He shows that the wages of the agricultural labourer have increased, while his hours have decreased. In the textile, engineering and house-building trades, he shows that the workman gets from 50 to 100 per cent. more money than fifty years previously for 20 per cent. less work. He sums up in the following general statement: 'While the workman's wages have advanced, most articles he consumes have rather diminished in price, the change in wheat being especially remarkable, and significant of a complete revolution in the condition of the masses. The increased price in the case of one or two articles —particularly meat and house-rent—is insufficient to neutralize the general advantages which the workman has gained.'

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* "The Progress of the Working Classes in the last Half-Century." by R. Giffen, F.R.S. (Inaugural Address, Statistical Society, Session 1883–84).

"The conditions of housing of a large proportion of the wage-earning classes are still unsatisfactory, and leave ample scope for improvement, though they have immensely improved as compared with fifty years ago. It must also be admitted that there is a considerable (though probably a diminishing) residuum who are not included in the general improvement described by Mr. Giffen.

"There are two other circumstances affecting the life of the community which must be considered in this connection. These are the effects of increasing 'urbanization' and the associated increase of manufacturing (and largely indoor) occupations as contrasted with agricultural and outdoor occupations.

"At the census of 1861, 37·7 per cent. of the total population of England and Wales was rural; at the census of 1881 this proportion had decreased to 33·4 per cent., and at the census of 1891 to 28·3 per cent. The urban death-rates are generally higher than the rural, though the former have shown a greater reduction in recent years than the latter. It is impossible to deny *in toto* that the conditions which go to form the sum total of urban life are less favourable to a healthy adult existence than those of rural life, though no attempt can be made at present to estimate the share of the increased number of the urban population in say 1871–80 as compared with 1838–54, in producing the higher adult death-rate at the more recent period.

"(*d*) Another consideration requires to be borne in mind. We are at present in a transition period. The Public Health Acts of 1871 and 1875 heralded immense improvements in sanitation, the fruits of which have not even yet been fully reaped. There has been, more especially since 1875, steady and increasing improvement in the conditions under which people live. Men now 40 years of age were born in the pre-sanitary period; and the first 20 years of their life were spent under more unhygienic conditions than those now holding good. This fact would go far towards explaining a stationary death-rate at the higher ages. It does not, however, explain an increased death-rate at those ages.

"The explanation of this increased death-rate at the higher ages will probably be evident when at the end of another twenty or thirty years the improved conditions of life have endured sufficiently long to enable their full force and value to be determined. We must be content in the meantime to have stated the more important factors which appear to be at work, leaving the complete solution of the problem to a time when the statistical experience of our country is more mature."

The preceding remarks have received, since they were written, valuable confirmation from the statistics of another decennium. The decline in the death-rate which when the eighth was compared with the seventh decade stopped short at adult life, has now extended to nearly every period of life in both sexes, though it is but small in amount after the forty-fifth year of life.

Distribution of Decreased Mortality according to Cause. In the following table the necessary data for a somewhat detailed comparison of the causes of death in successive periods are given. The caution given on p. 191 as to comparing death-rates from infectious diseases for groups of years must be held in remembrance in making this comparison. The aggregate zymotic diseases show a considerable decrease, fever showing a remarkable decline. Among the other named diseases the most remarkable features are the great decrease in phthisis, and the increase under the heads of cancer, and of respiratory, circulatory, and urinary diseases. The question as to how far these recorded increases are real is discussed on pp. 238 and 242.

ANNUAL MORTALITY FROM SEVERAL CAUSES PER MILLION PERSONS LIVING AT ALL AGES IN SUCCESSIVE PERIODS AND YEARS.

	1861-70.	1871-80.	1881-90.	1891-95.
All Causes	22416	21272	19080	18738
Small-pox	160	234	45	20
Measles	440	378	440	408
Scarlet Fever	972	716	334	182
Diphtheria	185	121	163	253
Whooping-cough	527	512	450	398
Fever—including Typhus	885	57	14	4
Fever—including Enteric		322	196	174
Fever—including Ill-defined		103	25	8
Puerperal Fever and Diseases of Childbirth	165	167	153	168
Diarrhœal Diseases	1076	935	674	651
Cancer	384	468	589	712
Phthisis	2475	2116	1724	1464
Hydrocephalus	347	317	696	660
Other Tubercular Diseases	437	445		
Diseases of Nervous System (including Convulsions)	2796	2789	2592	2288
Diseases of Circulatory System	1054	1339	1576	1677
Diseases of Respiratory System	3591	3899	3729	3747
Diseases of Digestive System	1184	1165	1104	1116
Diseases of Urinary System	266	350	435	453
Violence	765	733	648	663

CHAPTER XXVII.

STATISTICAL FALLACIES.

THE reservation of an entire chapter to the consideration of the fallacies into which those who employ figures frequently fall, appears almost as absurd as it would be to devote a chapter at the end of a treatise on grammar to the consideration of grammatical errors. The study of the science of grammar involves the exposure of grammatical errors; and similarly, if we have been successful in our attempt to treat of the principles of vital statistics, the fallacies which we so frequently meet with in medical statistics may be considered to be already sufficiently exposed. But while this is logically correct, there is a practical convenience in presenting a concise summary of the more important statistical errors, and especially so as this will enable us to consider in detail several cases which have not arisen in the preceding chapters.

We may first of all cite Quetelet's four chief rules, which are worthy to be held in remembrance.

(1) Never have preconceived ideas as to what the figures are to prove.

(2) Never reject a number that seems contrary to what you might expect, merely because it departs a good deal from the apparent average.

(3) Be careful to weigh and record *all* the possible causes of an event, and do not attribute to one what is really the result of the combination of several.

(4) Never compare data which have nothing in common.

Were these rules constantly followed, the science of statistics would be much more respected than it is, and the value of its results would be greatly increased.

Errors already Exposed. In the preceding chapters, numerous instances have arisen, illustrating various phases of statistical fallacies. Before considering other cases, it may be well to recapitulate those already mentioned.

Population forms an essential datum in the presentation of all vital statistics, and inaccurate estimates of population vitiate every subsequent calculation. Instances of such inaccurate estimates are given at p. 8. The errors arising in connection with the statement of age, infirmities, etc., are given at pp. 2 and 4. The age and sex constitution of the population has a great influence on the marriage-rate (p. 57), on the birth-rate (p. 71), and on the death-rate (p. 102); and unless due allowance be made for variation in composition of the population as to age and sex, especially as to age, serious errors will arise.

A correct and complete registration of causes of death is another essential datum in the presentation of vital statistics, and the chief errors in this connection have been already discussed (p. 29).

The questions of increase of cancer (p. 242), and of decrease of phthisis (p. 239) involve serious statistical difficulties, which have been already considered. The fallaciousness of the assumption that a fixed ratio exists between sickness and mortality has been discussed (pp. 37, 185).

We have stated that the birth-rate, to be strictly accurate, should be calculated in terms of the number of women living at child-bearing years (p. 72), and that the number of illegitimate births should not be stated in proportion to the total births (p. 82).

The fallacies connected with death-rates for short periods have been pointed out (p. 86), as also the effect of migration of population in disturbing the death-rate (p. 87), the effect of public institutions on the same (p. 89), and the fallacies as to the correct relationship of birth-rate to death-rate (p. 96). False methods of estimating the mortality at different ages have been exposed (p. 116). The sources of error in connection with occupational statistics are discussed at page 174, and, among other additional fallacies which have been considered, we may mention those in regard to small-pox (p. 208 *et seq.*), and in regard to the duration of life as evidenced by the mean age at death (p. 292).

Classification of Fallacies. Without attempting a complete logical classification of fallacies, we may divide them into *fallacies of observation* and *fallacies of inference.* The errors which we shall consider will be found to come under one of these heads, in some cases illustrating them both, the data and the inferences from them being each inaccurate or incomplete, or both.

Errors from Paucity of Data. The number of observations on which any deduction is founded should be considerable. The deduction is trustworthy in proportion as the observations are numerous, on the assumption that the latter are at the same time accurate and comparable. There is, unfortunately, nothing more common in medical literature than a crude generalization from insufficient data, especially as to the treatment of disease, ignoring the mathematical rule that the relative values of two or more series are as the square roots of the numbers of observations; so that by increasing the number of observations in any inquiry, the accuracy increases as the square root of the number. The results obtained, even from a large number of observations, are, however, only an approximation to the truth, although the limits of error are reduced with each increase in the number of observations.

The degree of approximation to the truth of a varying number of observations can be estimated by means of **Poisson's formula.** This formula can, however, only be entirely trusted in the ideal case of games of chance, in other cases forming an inadequate test of accuracy.

Let $\mu =$ total number of cases recorded,
$m =$ number in one group,
$n =$ number in the other group,
so that $m + n = \mu$.

The proportion of each group to the whole will be respectively $\frac{m}{\mu}$ and $\frac{n}{\mu}$. These proportions will vary within certain limits in succeeding instances, and the extent of variation will be within the proportion represented by

$$\frac{m}{\mu} + 2\sqrt{\frac{2 \cdot m \cdot n}{\mu^3}}$$

$$\text{and } \frac{n}{\mu} - 2\sqrt{\frac{2m \cdot n}{\mu^3}}.$$

It is evident that the larger the value of μ (the total number of observations) the less will be the value of $2\sqrt{\frac{2 \cdot m \cdot n}{\mu^3}}$ and the less will be the limits of error in the simple proportion $\frac{m}{\mu}$.

Thus if out of ten cases of cholera seven recover, how near is this to the true average of recoveries? Here the probability of recovering is represented by $\frac{7}{10}$, of dying by $\frac{3}{10}$. The possible error is given by the second half of Poisson's formula. Thus,

$$2\sqrt{\frac{2m\cdot n}{\mu^3}} = 2 \times \sqrt{\frac{2 \times 7 \times 3}{10^3}} = 2\sqrt{\frac{42}{1000}} = \cdot 4098.$$

Thus the possible error is as ·4098 to unity, or, in other words, the error is greater than the number of deaths. What will be the possible variation in 100,000 cases on this basis?

The average, as stated, is 70,000 recoveries out of 100,000 cases; the possible error is 40,980; therefore the number of recoveries may be either 29,020 or 110,980, a conclusion which is an obvious absurdity.

If, however, 100 cases be collected, out of which seventy recover, the proportion is the same; but by Poisson's formula the error is only ·13 to unity, and the range of recoveries out of 100,000 cases will lie between

$$70,000 + 13,000 = 83,000,$$
$$\text{and } 70,000 - 13,000 = 57,000.$$

If 1000 cases are taken, of which 700 recover, the error will be only ·04 to unity, and the range of recoveries in 100,000 cases will lie between

$$70,000 + 4000 = 74,000,$$
$$\text{and } 70,000 - 4000 = 66,000.$$

The following table will show more clearly how, with an increasing number of facts, the limits of possible error (assuming the accuracy of the facts recorded) steadily decrease :—

Total Number of Cases.	Number of Recoveries.	Possible Number Recovering out of 100,000 Cases according to Poisson's Formula.
10	7	29,020 *or* 110,980
100	70	57,000 „ 73,000
1000	700	66,000 „ 74,000
10,000	7000	68,700 „ 71,300
100,000	70,000	69,600 „ 70,400
1,000,000	700,000	69,870 „ 70,130

It is evident that a small number of observations is inadequate to establish a conclusion; but inasmuch as the degree of accuracy increases only in the ratio of the square root of the number of observations, the mere repetition of observations beyond a certain number (10,000 in the previous table) is proportionately of small value, and after a time becomes practically useless.

Errors from Inaccuracy or Incomparability of Data. Inaccuracy or incompleteness of data necessarily leads to fallacious conclusions. Apart altogether from any intentional deception, the trustworthiness and ability of the observer or recorder of a given set of facts is an important element in estimating the reliability of deductions from them. It is necessary that the data should be collected on a uniform plan, and should be of a strictly comparable nature. Any neglect in stating a single cause of variation in some of the facts may vitiate the entire conclusion. Thus it is well known that cholera is much less fatal towards the end of an epidemic than at its commencement. If, therefore, in stating the percentage of recoveries under a given method of treatment, no mention was made of the period of the epidemic when the cases came under treatment, a trustworthy conclusion would be impossible. The neglect of the precaution that the phenomena or *events dealt with shall be strictly comparable* has given rise to the most valid objections which have been urged against the use of the numerical method in medicine.

Dr. T. Graham Balfour, F.R.S., in his inaugural address as President of the Statistical Society (November, 1888), has given an interesting instance, arising from the alleged deterioration of recruits, of the fallacy due to overlooking the condition of "**other things being equal,**" which we shall now summarize.

It is stated, on the authority of the Director-General of the Medical Army Department, that in the years 1860-64 inclusive, no fewer than 32,324 examinations of recruits were made by army-surgeons; and that the rejections from all causes were 371·67 per 1000. During 1882–86, 132,563 men offered themselves for enlistment, of whom 415·58 per 1000 were rejected, showing a marked increase in the proportion of rejections. Sir Thomas Crawford can explain this increase in the rejections in one way only: "the masses, from whom the army recruits are chiefly taken, are of an inferior physique to what they were twenty-five years ago." Dr. Balfour, however, instituted independent inquiries, which threw grave doubt on this conclusion, and satisfied him that a large proportion, at least, of the striking excess of rejections at the later period was due, not to an increase in the disabilities among the recruits examined, but partly to improvements introduced into the returns in 1864, by which they were made much more complete, and partly to changes instituted in 1879 and 1880 in the system of examination.

Dr. Balfour's address must be consulted for full details, which make it clear that owing to the varying regulations in force in the army, it is impossible to arrange the results of the two series of years in a form which complies with the condition of "other things being equal."

Similar remarks apply to the question of height of recruits, and the proportion of recruits rejected in successive periods.

Errors in Comparing Total Deaths in Successive Years. It is inaccurate to compare the number of total deaths or the number of deaths from any one disease with the corresponding number in any previous year unless some allowance is made for increase of population. *Cæteris paribus*, a larger population would supply a greater number of deaths than a smaller one. We shall now demonstrate the method by which *the number of deaths in any year may be compared with the decennial average of the ten preceding years, corrected for increase of population during the period*, taking as an example the number of deaths from measles in England and Wales in 1887, and the average number in the decennium 1877–86.

The number of deaths from measles in 1887 = 16,765.

The average annual number of deaths from measles in the ten years 1877–86 = 10,549.

What was this average corrected for increase of population, in order to allow accurate comparison with the figures for 1887?

Now, the population of England and Wales in 1887 = 28,247,151.

The mean population of 1877–86, obtained by summation of the populations in each year and division by ten = 26,256,699. The deaths from measles in the decennium 1877–86 must therefore be raised in the proportion of 26,256,699 to 28,247,151, in order to bring them into true comparison with those of 1887.

$$\text{But } \frac{28247151}{26256699} = 1{\cdot}075.$$

By multiplying 10,549 by 1·075 we obtain 11,340, which represents the average annual number of deaths from measles during the decennium 1877–86, corrected for increase of population.

This number, subtracted from 16,765, gives 5425, which is the excess of deaths from measles in 1887 as compared with the mean of the previous decennium.

Errors in Regard to Averages. The larger the basis of facts on which an average is founded the more reliable it is. Accidental causes may produce large variations in a small series of observations, which become corrected when the facts are multiplied. It is on this principle that, in spite of the great annual fluctuations in the receipts and expenditure of Insurance Societies, the results become equalized for a series of years.

Dr. Guy gives the following instance of the value of increasing the number of facts on which an average is based, from an investigation into the average age at death of members of the peerage and baronetage:—

Number of Facts.	Average Age at Death.		
	Maximum.	Minimum.	Range.
25	69·40	50·64	18·76
50	66·44	55·20	11·24
100	63·70	56·85	6·85
200	62·38	57·61	4·77
400	61·10	58·24	2·86
800	60 84	59·97	1·17
1600	60·25		

If we assume the true average duration of life of the members of the peerage and baronetage who have attained 21 years to extend to 60 years, then, omitting decimal points, the following table shows the errors in excess or defect:—

Number of Facts.	Errors in Excess or Defect.
25	9½
50	5½
100	3½
200	2½
400	1½
800	0½

It may happen, however, that the first 25 observations in a table like the preceding would give as correct an average as 800 observations; and there is always a balance of probability in favour of the average of even a small number of facts approximating more closely to the true average than to the extremes. The extreme values, that is, the two ends of the scale, of which the average is the middle, should also be noted. As Dr. Guy puts it, "Averages are numerical expressions of probabilities; extreme values are expressions of possibilities." The possible range of the average obtained from a stated number of observations can always be ascertained by means of Poisson's formula, thus indicating the possible amount of error.

Although, as already stated, the average of a small number of facts may give a near approximation to the truth, such an average must be regarded as requiring a confirmation which the average from a large number of facts does not require. It is important to note also that *the results obtained from an average can never be applied to a particular case*. An average is the mean result from a number of instances, all of which may be either above or below it, so that it does not necessarily express the exact truth in regard to any one of the cases on which the average is founded.

The fallacies connected with the application of the results of a large number of cases to an individual instance are well known to insurance offices. General results from a large aggregation of facts may be safely applied to a similar aggregation of facts; but their application to single cases is full of dangers. Thus, the mean duration of life, according to a life-table, expresses with almost mathematical certainty the average age at death of the members of a community *taken one with another*, but is not necessarily accurate when applied to a single individual. All that we can safely conclude is, that the excess of those who live longer will be counterbalanced by the deficiency of years of those who die at an earlier age than the average.

Extremes, being the expression of possibilities, require a larger number of individual facts than averages to render them trustworthy. Dr. Guy gives an interesting instance of neglect of this rule. M. Orfila stated that it was possible approximately to determine the stature of the skeleton and of the body by measuring one of the long bones. He did not test this, however, by taking extreme cases, but only by a rough average. It was subsequently found that out of seven ulnas, measuring in length

10 inches and 8 lines, one corresponded to a stature of 6 ft. 1¼ in., another to 5 ft. 5 in., implying a possible error of 8¼ inches.

In connection with public health, two fallacious uses of averages must be discussed, viz., the fallacy of average strength, and of bed-mortality in hospitals, which are closely connected.

Errors in Connection with Average Strength. The sickness and mortality statistics in the army and navy are calculated on what is known as the *average strength* or *mean force.* It is not quite clear, from the annual report of the Army Medical Department, whether the mean force includes those on sick leave as well as detached men, but apparently these are included. In the navy the mean force has been recently made to include men on short terms of leave of absence and the sick under treatment in hospital —a change which has been found to increase the force by 3 per cent. According to Dr. Parkes, the average strength includes in the army the number of men of each regiment present at each station on the muster days, divided by the number of muster days. It thus includes the sick men in hospital as well as the healthy men, and is consequently not a completely accurate basis on which to determine the amount of disease among the healthy men. When many changes of troops occur, it is often difficult to ascertain the mean strength, and erroneous calculations are consequently not uncommon. An example, quoted by Dr. Parkes from a paper by Dr. Balfour, may be cited, which is of special interest, inasmuch as it affords an instance in which an unhealthy station in India (Masulipatam) was credited with a more favourable rate of mortality than it was entitled to. The Madras Medical Board stated that the death-rate among all the European regiments in the Presidency, from January, 1813, to December, 1819, was 56·9 per 1000; while that of the regiments at Masulipatam from 1813 to 1832 inclusive was 51·0 per 1000; and they inferred that the rate of mortality having been somewhat lower than throughout the rest of the Presidency for such a period, there was reason for concluding that the station could not be considered under ordinary circumstances as unhealthy. In arriving at the preceding death-rate for Masulipatam, however, the fact had been lost sight of, that in several of the years between 1813 and 1832, the regiments were quartered at Masulipatam during part of the year only. Under such circumstances, in calculating the annual death-rate, only such a proportion of the mean annual strength should be taken as corresponded with the period during which the regiment was stationed there. If it was stationed there six months, the calculation should be based on half the strength; if nine months, on three-fourths of it, and so on.

When the necessary correction was made in the instance cited, the annual death-rate from 1813 to 1832 was found to average 63·94 per 1000, instead of 51·00 as previously stated.

The error we have just described is similar to the assumption that, in a town with a population of 100,000 persons, and in which 3000 deaths occurred during nine months, the annual death-rate is 30 per 1000. The population should, of course, be reduced by one-fourth; and the annual death-rate, on the assumption that the same rate of mortality continues during the remaining three months of the year, is 40 per 1000.

Fallacies of Hospital Statistics. Much of the misapprehension which has arisen in medical literature concerning hospital mortality is owing to a lack of comprehension of the facts relative to average strength, which we have already adduced. The subject is discussed very lucidly in the Sixth Report of Mr. (now Sir John) Simon to the Privy Council for 1863; and we cannot give a better view of it than by summarizing his argument, founded on an investigation made by Dr. Bristowe and Mr. Holmes into the sanitary conditions of, and results obtained in, various large hospitals.

To begin with, the word "healthy," as applied to a hospital, evidently cannot denote that its inmates shall be persons in health; nor that its inmates shall not have a high death-rate, for this is involved in the condition of the inmates. A "healthy" hospital is one "which does not *by any fault of its own* (whether *inherent fault*, as of site or construction; or *fault of keeping*, as dirtiness or overcrowding) aggravate ever so little the sickness, nor oppose ever so little the recovery of persons who are properly its inmates."

Death is unquestionably the most serious form in which lack of success in treatment is evidenced. It is essential, however, if hospital death-rates are to possess the slightest value, that they should be calculated on *given magnitudes of illness*. The comparison of the death-rate in a fever hospital with that in an orthopœdic hospital would obviously be absurd. Unless due regard be had, therefore, to the uncertain import of the word "patient," death-rates are worthless as evidence of success or failure in hospital treatment. It is notorious that hospitals, with regard to the quality and magnitude of the cases received in them for treatment, differ enormously from one another. Large urban hospitals receive patients at any time and of the gravest character, and "wage an ever-precarious contest against the least conquerable forms of disease"; while in many country hospitals admission is by subscriber's letter, there is a comparatively infrequent change of patients, and a minimum of severe or urgent cases. On the whole, it may be safely asserted that the hospitals with high death-rates have no reason to be ashamed, nor the hospitals with low death-rates to congratulate themselves.

The Registrar-General published in his Twenty-fourth Annual Report some statistics of the different hospitals. The census on April 8th, 1861, showed how many special inmates were contained in each of the hospitals of England, while the death-returns of the year 1861 showed how many deaths occurred during the year in the same hospitals. From these materials an annual death-rate per 100 occupied beds, which may be called a *bed death-rate*, was compiled. Such bed death-rates are most misleading. (*a*) In the first place, they were calculated on the hospital population of a single day—that of the census, which may have been much above or below the average—and not on the average daily sick population. Dr. Buchanan showed that, accepting the number of inmates at the census day in 1861 as the basis of calculation, the bed death-rate of the London Fever Hospital in 1860 was nearly 30 per cent., in 1861 nearly 500 per cent., in 1862 nearly 2000 per cent., and in 1863 nearly 1400 per cent.

(*b*) Each bed in a hospital usually receives during the year a succession of patients. All that a bed death-rate means is that there occurs in every occupied bed in a hospital a certain number of deaths per annum. A bed death-rate of 100 per cent. per annum means that on an average one death occurs during the year in every occupied bed of the hospital.

(*c*) These objections, however, are trifling when compared with the objections already stated against all general death-rates as measures of hospital healthiness. A table given in the Registrar-General's report alluded to, shows the striking and suspicious disparity between the bed death-rates of different hospitals.

Thus the Nottingham hospital had a bed death-rate under 41, while that of Manchester was over 130; at Swansea the death-rate was only 10, while at Bath it was 102, per 100 occupied beds.

These results are quite untrustworthy. Assuming that the mortality in urban hospitals is twice as great as in rural hospitals, then we might conclude any one of three things: "either (1) that the urban hospitals change their sick population twice as often as the rural hospitals, and that other conditions are equal; or (2) that in the urban hospitals the mean gravity of cases received for treatment is twice as great as in the rural hospitals, and that other conditions are equal; or (3) that in the urban hospitals the success of treatment of given magnitudes of disease is half as great as in the rural hospitals, and that other conditions are equal." In all probability the two first of these suppositions express the truth, though unfortunately Dr. Farr gave the authority of his name to the statement that general hospitals, by reason of "defects" which "render them ways of death to their inmates," do "not benefit mankind directly," but merely "as pathological observatories and medical schools"; and Miss Florence Nightingale, in her *Notes on Hospitals*, has accepted Dr. Farr's conclusions as valid. The real fact is that general death-rates are inapplicable as tests of true differences of hospital success, and ought never to have been employed for this purpose.

If general death-rates are employed at all in regard to hospitals, the true principle on which to calculate them is on the basis of the aggregate annual number of cases treated to a termination. This may be called the *patient death-rate*, as distinguished from the bed death-rate already described. There is no necessary connection between the range shown by bed death-rates in the preceding table and the range of patient death-rates in the same institutions. Whether the two ranges would correspond depends on whether *the average time of staying in hospital* is the same in the hospitals compared. But as a matter of fact the staying-time varies enormously in different hospitals, being usually shorter in larger hospitals, and shorter in hospitals where the proportion of acute cases is high. If the mean stay of patients in hospitals is known, *bed death-rates* may at once be converted into *patient death-rates* or *vice versâ*.

It follows from the preceding considerations that comparisons of hospital statistics, if they are to serve any useful purpose, must be in considerable detail. Not only should cases of like nature be compared, but, inasmuch as the mortality from many diseases varies with age, the age-constitution of the patients of the institutions under comparison should be noted. A typhus patient aged 55 is at least ten times as likely to die as a typhus patient aged 15. Similarly the success of the operation of lithotomy varies greatly at different ages.

The success of the major amputations again varies greatly according to the age of patients, and according to whether operation is required as the result of injury or disease; and in regard to all statistics dealing with the results of treatment, it is desirable that the age and special circumstances of the individual cases should be fully stated.

Errors from the Composition of Ratios. As a general rule, it is dangerous in dealing with deaths and other rates to combine or compound such rates. This error is so commonly fallen into that the following illustrations of the resulting mistakes cannot be considered superfluous:—

Thus the population of—

Battersea	was 125,091	and its death-rate	20·00
Putney	„ 14,450	„ „ „	13·70
			33·70
		Mean death-rate of the two =	16·85

This, however, is a most incorrect result. The true method is as follows:—

Battersea	population, 125,091;	deaths,	2503
Putney	„ 14,450;	„	199
	139,541		2702

Therefore $\frac{2702 \times 1000}{139{,}541} = 19{\cdot}59$ is the true death-rate.

The true death-rate is thus seen to be much higher than that first obtained, owing to the fact that in the first calculation equal prominence is given to the healthiness of Putney and of Battersea, although Putney had only one-eighth of the entire population.

Another instructive and somewhat amusing instance is furnished by a correspondence in the *Times* during September, 1888. *X* wrote to the *Times* newspaper, and on the assumption that the death-rate in the British army at home and abroad in 1885 was 11·12 per 1000, and the death-rate of troops at home 6·68, argued gravely that the death-rate of troops abroad was therefore 4·44 per 1000! *Y* wrote to correct this statement, and pointed out that if *X*'s method were correct, then it would be equally true that if the death-rate of the English and Irish in the United Kingdom was 21 per 1000 and that of the Irish 20 per 1000, the mortality of the English was only 1 per 1000; or if the death-rate of the Irish was over 21, then the English live for ever! *Y* then proceeded to maintain that the true mortality of the troops abroad was 15·56 per 1000, without mentioning, as *Z* pointed out in a subsequent letter, that this was only correct when the troops at home and abroad were equal in number; on which *Y* replied that "rates per 1000 are quite irrespective of numbers at home and abroad"—a conclusion which is true for rates regarded separately, but flagrantly false when applied to their composition. As this question of the composition of rates is one of considerable delicacy and importance, we shall here discuss it in detail.

The general problem to be considered is as follows:—Having given the death-rate of the component parts of a population, to find what is the death-rate for the whole.

Let $a+b$ = total number of population (or body of men, as in preceding example), where a and b represent the population of each part.

Also let x = death-rate per unit of the portion a,
and y = ,, ,, ,, ,, b,
Where x differs from y.
Then the number of deaths in $a = a \times x = ax$.
Also ,, ,, ,, $b = b \times y = by$.

Therefore the total number of deaths in $(a+b) = ax + by$. Hence, dividing by the total population, we obtain—

$$\frac{ax+by}{a+b} = \text{death-rate per unit for the whole.}$$

If the two parts of the population are equal; *i.e.*, if $a = b$,

$$\text{the death-rate for the whole} = \frac{ax+ay}{a+a} = \frac{a(x+y)}{2a} = \frac{x+y}{2},$$

which is the mean of the two rates x and y.

Hence, when the parts of which a population is composed are equal, the death-rate of the whole is the mean of the death-rates of the component parts.

But if a be twice as great as b; *i.e.*, if $a = 2b$, then the formula $\frac{ax+by}{a+b}$ may be written $\frac{2bx+by}{2b+b} = \frac{b(2x+y)}{3b} = \frac{2x+y}{3}$ where evidently the death-rate for the whole is not the mean of the death-rates for the two parts.

From this it is evident that when the death-rates of the component parts of a population are given, the death-rate of the whole population will depend on the relative proportion existing between the component parts of the population; and any variation in these proportions will cause a corresponding variation in the total death-rate. In order, therefore, to ascertain the total death-rates from the death-rates of the parts, we must either know the actual population of each component part or their relative proportions.

Reverting once more to the formula already given, viz., $\frac{ax+by}{a+b}$ = death-rate per unit of the population $(a+b)$, it is evident that, where the total death-rate is given and the death-rate of one component part of the population, this same formula will enable us to find the death-rate of the remaining portion.

Thus, taking the example already quoted from the *Times* newspaper,

The death-rate of the army at home and abroad in 1885 = 11·12 per 1000.

The death-rate of the army at home = 6·68 per 1000.

To find the death-rate of the army abroad. From the Registrar-General's returns, we find the strength of the total army in 1885 = 198,064; of the army at home = 91,579; of the army abroad = 105,748.

By the formula $\frac{ax+by}{a+b} = 11{\cdot}12 = \frac{91579 \times 6{\cdot}68 + 105748 \times y}{198064}$,

From which we obtain the result that $y = 15$ nearly.

Similarly, having given the death-rate of the army in the United Kingdom in 1887 to be 5·3 per 1000, of the army abroad 14·0, to find the death-rate of the total army, the strength of the army in the United Kingdom being 106,767, and of the army abroad 102,807.

Death-rate of the whole army

$$= \frac{ax+by}{a+b} = \frac{106767 \times 5{\cdot}3 + 102807 \times 14{\cdot}0}{106767 + 102807}.$$
$$= 9{\cdot}6.$$

The use of the death-rate per 1000 instead of per unit in these calculations does not alter the result, as it affects both numerator and denominator equally.

Another example may be taken. Having given the population of the twenty-eight great towns (including London) as 9,398,273, and their death-rate per annum for the quarter ending December 29th, 1888, as 19·8 per 1000, the population of London as 4,282,921, and its death-rate for the same period 18·9 per 1000; to find the average death-rate for the other twenty-seven towns:—

Let z = total death-rate, then—

$$z = \frac{ax + by}{a + b}; \text{ whence}$$

$$ax + by = z(a + b),$$
$$by = z(a + b) - ax,$$
$$y = \frac{z(a + b) - ax}{b}.$$

$$\text{Therefore } y = \frac{19{\cdot}8(4282921 + 5115352) - 18{\cdot}9 \times 4228921}{5115352},$$
$$= \frac{105138598{\cdot}5}{5115352} = 20{\cdot}5.$$

Fallacies arising from stating Deaths in Proportion to Total Deaths. These have already received consideration (pp. 124, 186). They present themselves under two heads. The deaths at one age are stated in proportion to the total deaths at all ages; or the deaths from one cause are stated in proportion to the total deaths from all causes. In both cases the same fallacy is involved. A relationship is attempted to be established *between two factors, both of which are variable* in value. An alteration in the total deaths on one hand, or in the deaths at one group of ages or from one cause on the other hand, might equally affect the proportion between the two, though the conclusions to be drawn in the two cases would by no means be necessarily identical.

CHAPTER XXVIII.

STATISTICS OF SICKNESS.

WE have in Chapter V. discussed the subject of registration of sickness, and have emphasized the importance of a more general registration of sickness, not confined to the chief infectious diseases.

So far as the diseases notifiable under the Infectious Diseases (Notification) Act are concerned, there is gradually accumulating a valuable mass of information, which will become more valuable with every additional year. It is impossible here to summarize any of this evidence, but the following figures for London, derived from the Annual Report of the Medical Officer of Health of the Administrative County of London, may be taken as examples.

CASE-RATE PER MILLION OF POPULATION.

	1891.	1892.	1893.	1894.	1895.	1896.
Small-pox	27	100	653	274	223	50
Scarlet Fever	2700	6400	8600	4300	4500	5700
Diphtheria	1500	2000	3200	2600	2600	3100
Typhoid Fever	800	600	900	800	800	700
Erysipelas	1130	1630	2260	1400	1300	1430
Puerperal Fever, (*a*) case-rate per million of population	50	80	90	60	50	60
(*b*) Case-rate per million births	1640	2550	2980	1920	1760	2040

The notification returns have been utilized by Mr. Shirley Murphy to form some very suggestive tables as to the seasonal variations in age-distribution of scarlet fever, and the seasonal variations of fatality of diphtheria and of scarlet fever.

The tables show that the children under five years of age who were attacked with scarlet fever in London, 1892-6, constituted at the beginning and end of the year a larger proportion of the total number of persons attacked than at other times.

The fatality from scarlet fever in London is highest in the early months of the year, declining generally in succeeding months to a minimum in September or October. Corrections made for difference in age and sex-distribution of the cases of each month appeared to show that these differences were insufficient to account for the above variations in the fatality. The figures supplied by diphtheria point in the same direction as those for scarlet fever.

The materials are lacking for a complete study of the amount of illness in this country, in the absence of any complete system of registration of disease; and estimates of the amount of non-infectious illness can only be based on the records of sick-clubs and benefit societies, and the official returns of the Army, Navy, and Police .

No distinct line of demarcation exists between health and sickness, and the two are connected by a series of intermediate states. Only sickness which is sufficiently severe to involve confinement to bed or house, or to incapacitate for labour, is in practice capable of being registered; and even in regard to this disabling sickness our information is very partial.

The following table, from the article by Dr. Farr in McCulloch's *Account of the British Empire* (1854), shows the time lost by sickness and by accidental injury among the labourers in Portsmouth and Woolwich dockyards :—

	Mean Number of Workmen.	Days Lost by Sickness.	Days Lost by Accidents.	Constantly Sick per cent.	Constantly Suffering from Accidents per cent.	Constantly Ill from both Causes per cent.
Portsmouth	5939	27410	15590	1·26	0·73	1·99
Woolwich .	2243	10593	8594	1·29	1·05	2·34

The following table has been condensed from a similar table in a paper by Dr. J. Bertillon (*Journal Royal Statistical Society*, vol. lv. part iv.). It gives a valuable summary of the sickness experience of Friendly Societies.

AVERAGE NUMBER OF DAYS OF SICKNESS PER ANNUM OF MEMBERS OF VARIOUS AGES.

AGE.	ENGLISH TABLES.			GERMAN TABLES.			DANISH.	FRENCH TABLES.				ITALIAN TABL		
	English Friendly Societies (Males).	Manchester Unity of Oddfellows (Males).	Foresters (Males).	Leipzig Assurance against Sickness and Invalidity.	Railway Servants.	Travelling Railway Servants.	Workmen at the Copenhagen Arsenal.	Twenty-Five Mutual French Societies (*circ.* 1835–49).			Lyons Silk-workers (Males).	162 Italian Mutual Aid Societies (Males).	Mutual Italian Societies (Males). (1881–85.)	
	A. G. Finlaison.	H. Ratcliffe.	F. G. P. Neison, jun.	Heym.	Behm.		Finger.	G. Hubbard.			J. Bertillon.	Bodio.	Bodio	
Years.	1846–50.	1866–70.	1871–75.	1856–75.	1870–77.		1825–40.	Sickness.	Infirmity.	Total.	1872–89.	1866–75.	Actual Results.	Corrected Results.
20–25	6·90	5·28	5·73	5·8	8·3	12·6	10·3	5·13	0·35	5·48	3·06	6·5	4·6	5·0
25–30	6·90	5·64	5·97	5·1	7·5	11·7	9·5	5·33	0·46	5·79	3·40	6·0	5·0	5·1
30–35	6·80	6·50	6·78	5·6	7·7	13·1	7·6	4·71	0·46	5·17	3·37	6·1	4·8	5·1
35–40	7·64	7·44	8·05	6·3	9·0	15·2	7·8	5·23	0·58	5·81	4·32	6·3	5·6	6·0
40–45	8·59	8·82	9·62	7·8	10·0	16·3	8·3	6·21	1·98	8·19	5·29	6·8	5·8	6·2
45–50	10·06	11·45	11·95	7·7	11·3	19·0	11·6	6·40	2·01	8·41	5·89	7·1	6·4	6·8
50–55	12·48	15·55	15·85	8·5	14·3	24·2	14·1	6·40	2·68	9·08	8·04	7·5	7·4	7·9
55–60	15·24	21·30	22·48	16·3	17·5	30·6		8·85	2·85	11·70	8·38	8·9	8·7	9·2
60–65	21·82	33·00	32·13	12·5	18·1	—	—	11·03	8·47	19·50	11·15	11·2	10·5	11·2
65–70	32·39	50·60	55·80	18·9	15·0	—	—	10·63	16·39	27·02	16·73	12·4	12·6	13·1
70–75	53·65	84·50	84·00	—	—	—	—	12·54	53·50	66·04	19·76	11·0	13·9	14·7
Age unknown.	—	—	—	—	—	—	—	8·29	13·46	21·75	—			
All Ages.	10·11	10·46	9·51	—	—	—	—	6·21	2·49	8·70	7·80	6·9	6·2	6·6

The following table is derived from the *Report on Sickness and Mortality Experienced in Registered Friendly Societies** :—

Description and Nature of Experience.	Exposed to Risk of Sickness.	Exposed to Risk of Death.	Average rate per annum in weeks	
			Of Sickness.	Of Mortality.
Males (1856-60)	722338	788891	1·61	·011
Females, England and Wales (1856-75)	139122	146793	2·34	·014
Wales, Males (1856-75) .	167255	177897	2·14	·015
Males (1876-80)	1662561	1662561	1·89	·014
Males (1861-70)	1789532	1789532	1·79	·014
	4480808	4565675	1·83	·013

For the sickness statistics of the army and navy the reader is referred to the annual reports of the medical departments of these services.

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* Eyre and Spottiswoode, 10*s.* 9*d.*

CHAPTER XXIX.

MISCELLANEA.

GRAPHIC Methods. It had been intended to write a special chapter dealing with graphic methods of stating statistical facts. Instead of this, illustrations of the method have been introduced throughout the book, which it is hoped will sufficiently prove the value of this method. The special application of the graphic method to the construction of a life-table is given on p. 266, and a similar method is described on p. 246 for cancer mortality.

Certain cautions are required in applying the graphic method. By comparing curves, the scale of which is not identical, an erroneous conclusion has often been obtained. I am now speaking of diagrams constructed as parallelograms, of which the length (*axis of the abscissæ*) represents time, and the height (*axis of the ordinates*) represents mortality. A remarkable instance from Dr. Wallace's writings of the fallacy introduced by compressing the vertical scale of a diagram is given by Dr. McVail (*Vaccination Vindicated*, p. 2 *et seq.*). The fallacy introduced by such a reduction of the vertical scale can be demonstrated by ascertaining the average death-rate from a given cause for a series of years, and then stating the death-rate for each year as a percentage deviation from this average death-rate (*Buchan and Mitchell's method*). An example of this method is given in Fig. 25.

Spot maps are frequently employed to indicate the incidence of infectious diseases in a town. It is doubtful if the maps of this description, published in the annual reports of the Metropolitan Asylums Board and of many medical officers of health, have more than a fractional value. They serve rather to indicate the density of population and the districts in which the largest proportion of children live, than the true prevalence of an infectious disease. Perhaps an exception may be made in the case of spot maps of the annual incidence of typhus fever, as these would commonly indicate districts requiring the application of the Housing of the Working Classes Act. The true utility of a spot map consists in its employment in the office of a medical officer of health, where each case, plotted out as soon as it is notified, may serve to indicate the course of infection.

Means and Averages. Throughout this work these terms have been employed as interchangeable and as indicating the arithmetical mean of a given series. It must be noted that if the mean of a series of *death-rates* a, b, c, d, and e is taken in accordance with the formula, *arithmetical* mean $= \frac{a+b+c+d+e}{5}$, an error is introduced if the number of deaths or of the population varies in the different years. The only accurate method is to add together the populations for each of the series of years, then the deaths in like manner, and from these deduce the mean death-rate for the entire period. (See footnote, p. 212.)

In mathematics there are three other means, viz. :—

the *geometric* mean, $\sqrt[5]{a\,b\,c\,d\,e}$,

the *harmonic* mean, $\dfrac{5}{\frac{1}{a}+\frac{1}{b}+\frac{1}{c}+\frac{1}{d}+\frac{1}{e}}$,

and the *quadratic* mean, $\sqrt{\dfrac{a^2+b^2+c^2+d^2+e^2}{5}}$.

If the terms of the series are equal, the above means are all identical. If the terms are unequal, the quadratic mean is the highest, next the arithmetic, and then the geometric and harmonic means.*

The value of a series of observations increases with the number of observations. The value of a given series may also be tested by taking *successive means*. Thus if $\frac{a+b}{2}$, $\frac{a+b+c}{3}$, $\frac{a+b+c+d}{4}$, and so on be calculated, marked differences in means may be at first visible, but they become rapidly smaller with increasing length of the series if the series is a trustworthy one. The *error* of a given series is the deviation of its individual terms from its mean. The *mean error in excess* is the arithmetical mean of the errors of those terms above the mean of the series; the *mean error in deficiency*, the arithmetical mean of the errors of those terms below the mean of the series; while the *mean error of the series* is the average of these two.

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* See papers on the "Importance and Value of Arithmetical Means," by Professors RADICKE and VIERORDT (*New Sydenham Soc.*, vol. xi).

The *probable error* is obtained by multiplying the mean error of the series (derived as above) by ·67449 or by ⅔. The errors would fall short of this quantity as often as they would exceed it.

The *error of mean square* is obtained from the quadratic mean as follows:—If q = quadratic mean, and a = arithmetical mean, in a series of n terms, then

$$\text{error of mean square} = \frac{q-a}{n^2-n}.$$

(For a full discussion of the above subject see Radicke, *op. cit.*, De Morgan's *Essay on Probabilities*, and Airy's *Errors of Observations*, p. 18 *et seq.*)

For a statement of Poisson's formula see p. 323.

Fatality. The case-mortality, or fatality of patients, must be stated in proportion to the number of cases treated.

The usual plan is to divide the deaths multiplied by 100 by half the sum of the admissions, discharges, and deaths for the year, or the period of inquiry. The importance of classifying patients according to age must not be overlooked.

Probability of Recurrence of a Disease apart from Infection. In attempting to solve problems as to the special incidence of a particular house or group of houses, *e.g.*, phthisis or cancer, there are serious fallacies, unless special precautions are taken. First, there is the question of chance. It may be a mere coincidence that successive cases of, let us say, cancer have occurred in a particular dwelling. De Morgan showed that if a sufficient number of persons were set to work tossing pence, one of these persons would eventually, if he continued the operation for a sufficient length of time, turn up "heads" for a thousand times in succession, without a single interval of "tails." It is plain, therefore, that the fact that several successive families living in a house have each had members suffering in this house from cancer, does not necessarily prove a causative relationship between the condition of the house or of the soil on which it is built, and the origin of the disease.

Secondly, there is the question of age-incidence. The tendency to cancer increases rapidly with advancing years. As according to Dr. Ogle's calculations at least one out of twenty-one men and one out of twelve women who reach the age of 35 eventually die from cancer, it would be surprising if in residential towns and districts there did not frequently occur a succession of deaths from cancer in a particular house or group of houses. Careful correction must be made for age-distribution of the population, and the amount of cancer in the houses investigated shown to be very markedly in excess of that in others, before any influence of locality or house-infection can safely be predicated.

Dr. Niven, in his annual report for the city of Manchester for 1897, gives the following investigation of the house-incidence of enteric fever, in which (apart from the question of age-incidence, which probably does not seriously affect the conclusions in this case) correct methods are pursued.

He first assumes that all the houses in the city are equally liable to invasion. Then, excerpting the average number of houses affected once in the seven years, the chance of any one house being affected in any one year is

$$x = \frac{\text{Average number of houses affected}}{\text{Average number of occupied houses}}.$$

Let m be the number of years over which the inquiry extends. The chance of any house being affected in two different years is $\frac{x^2m(m-1)}{2}$, and the chance of a house being thrice invaded in separate years is $\frac{x^3m(m-1)(m-2)}{6}$. The number of houses which we should expect to be invaded on these suppositions is:—

Affected twice, $\frac{x^2m(m-1)}{2} \times$ average number of occupied houses in the city; affected thrice, $\frac{x^3m(m-1)(m-2)}{6} \times$ average number of occupied houses in the city.

$$\text{Now } x = \frac{490}{106721}, \text{ and } m = 7.$$

$$\text{Hence } \frac{x^2m(m-1)}{2} \times \text{average number of houses} = 47 \cdot 2.$$

The actual number twice invaded is 78. The excess of actual over the calculated recurrences is thus 31, or if we reckon the two double recurrences, 33. $\frac{x^3m(m-1)(m-2)}{6} \times$ average number of houses = 0·35, while the actual number of recurrences three times is 2. It will be seen, then, that there is an excess of actual recurrences, but not a great and striking excess. It may be doubted, however, whether the persistence is to be looked for so much in the house itself as in neighbouring houses, assuming that it is due to growth of infective matter in the soil outside the house.

Then, moreover, we should perhaps expect the excess to be more marked if we take successive years.

The expectation of recurrence in successive years, the number of the years being seven, is $6x^2$, and the number of such expectation recurrences is 13·5. The number of actual recurrences is 20. Here also, then, there is an excess of the actual over the expectation recurrences.

Dr. Niven concludes that the facts would probably yield more evidence if examined in a more elaborate manner. Thus, for example, the list of recurrences show a special tendency to recurrence in West Gorton, and a separate calculation for that district would probably yield more evidence of persistence. On the other hand, the calculation will not stand small figures, being essentially of a rough character, and subject to material deductions on the ground of doubtful diagnosis.

Calculation of Population of Sub-Districts. When the populations of a town or district and of its constituent sub-districts are calculated by the Registrar-General's method, the summation of the latter is not equal to the former. The correct populations for the sub-districts may be obtained by the use of the following formula given by Dr. L. Parkes (*Public Health*, vol. v. p. 191). First, the populations of the district and of its sub-districts are calculated by the Registrar-General's method (p. 6).

Then, if P = estimated population of entire district in 1898,
and p = census ,, ,, ,, 1891;
and if P_1, P_2, P_3 =
estimated populations of the constituent sub-districts in 1898,
and p_1, p_2, p_3 =
census populations of the constituent sub-districts in 1891,

$$\text{then } P = \frac{p_1}{p}P + \frac{p_2}{p}P + \frac{p_3}{p}P,$$

$$\text{where } \frac{p_1}{p}P \quad \frac{p_2}{p}P \quad \text{and } \frac{p_3}{p}P$$

are the correct populations of the three sub-districts in 1898.

Aids to Calculation. It is assumed throughout that the student is familiar with the use of tables of logarithms. I have found Jackson's Accented Five-figure Logarithms (W. H. Allen and Co.) very useful, as with these it is unnecessary to calculate differences. For the majority of the calculations required in medical statistical work, Crellé's Multiplication Tables, or the Direct Calculator of M. B. Cotsworth (York, 21*s.* nett) are more expeditious than logarithmic tables, and simply invaluable for every-day work. Fuller's Slide Rule is also useful, but in my experience is not so convenient as Crellé's or Cotsworth Tables.

POSTSCRIPT.

The Bertillon Classification of Causes of Death. While this Edition is passing through the press, the author's attention has been drawn to this system, which is about to be adopted in the United States, Canada, and Mexico, and possibly in other countries, as well as France. It has an anatomical basis, like Farr's classification, and can be employed so as to include 40 diseases, or 89, or 142, according as a less or more complete classification is required. The three arrangements are arranged so that statistics obtained under any one of the three are comparable.

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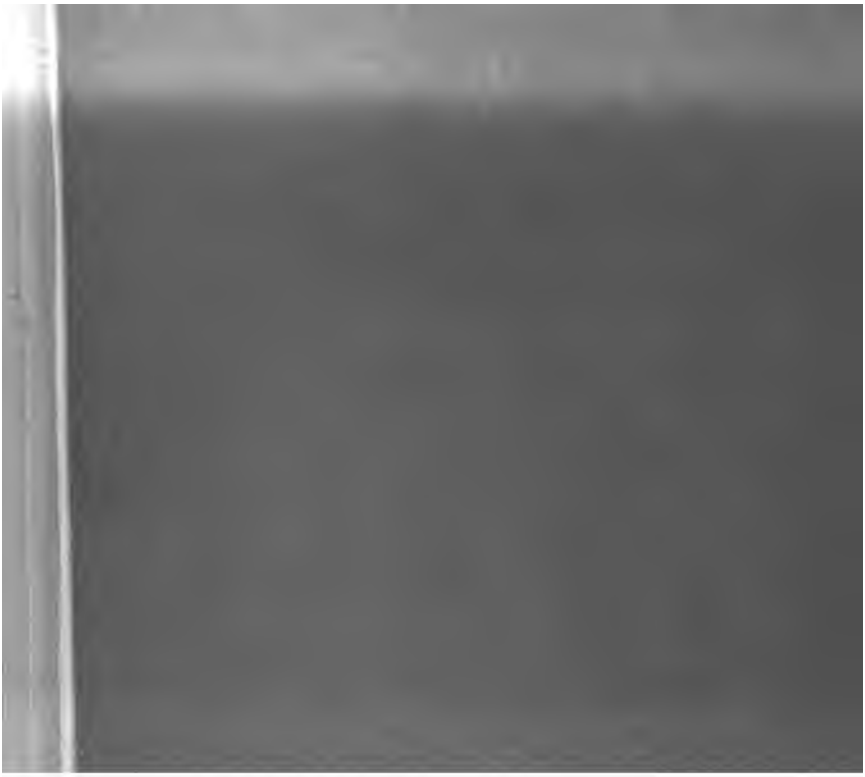

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